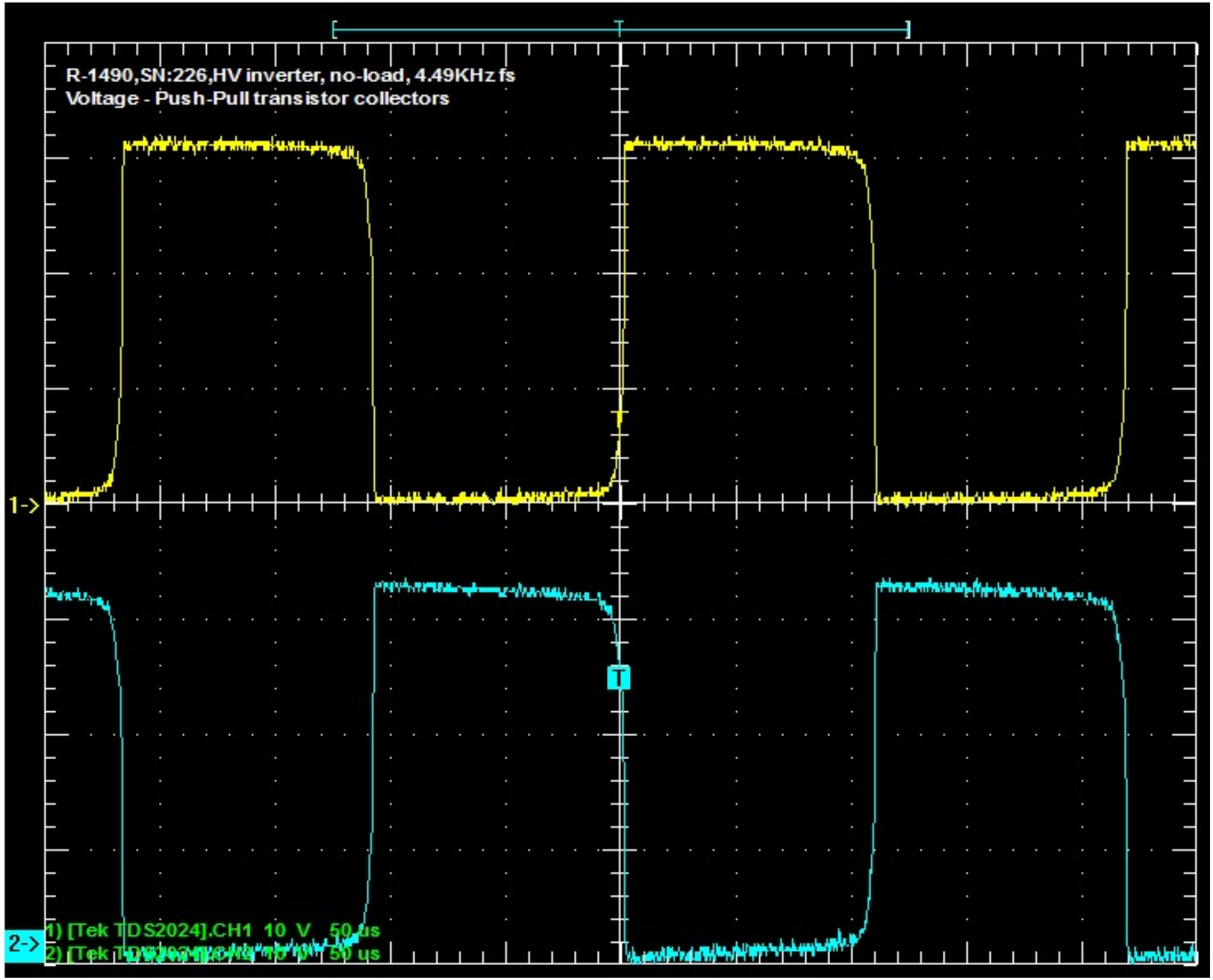
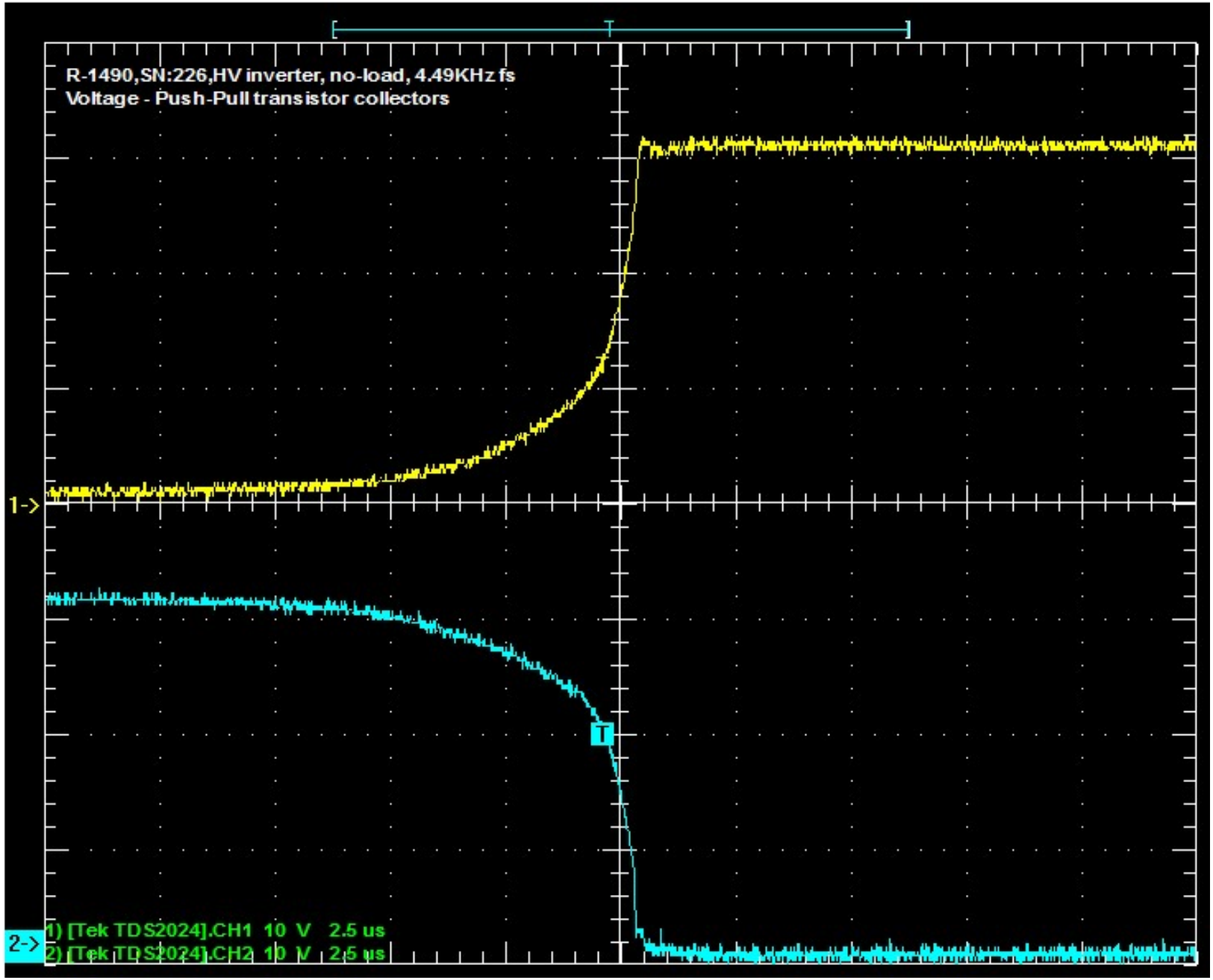
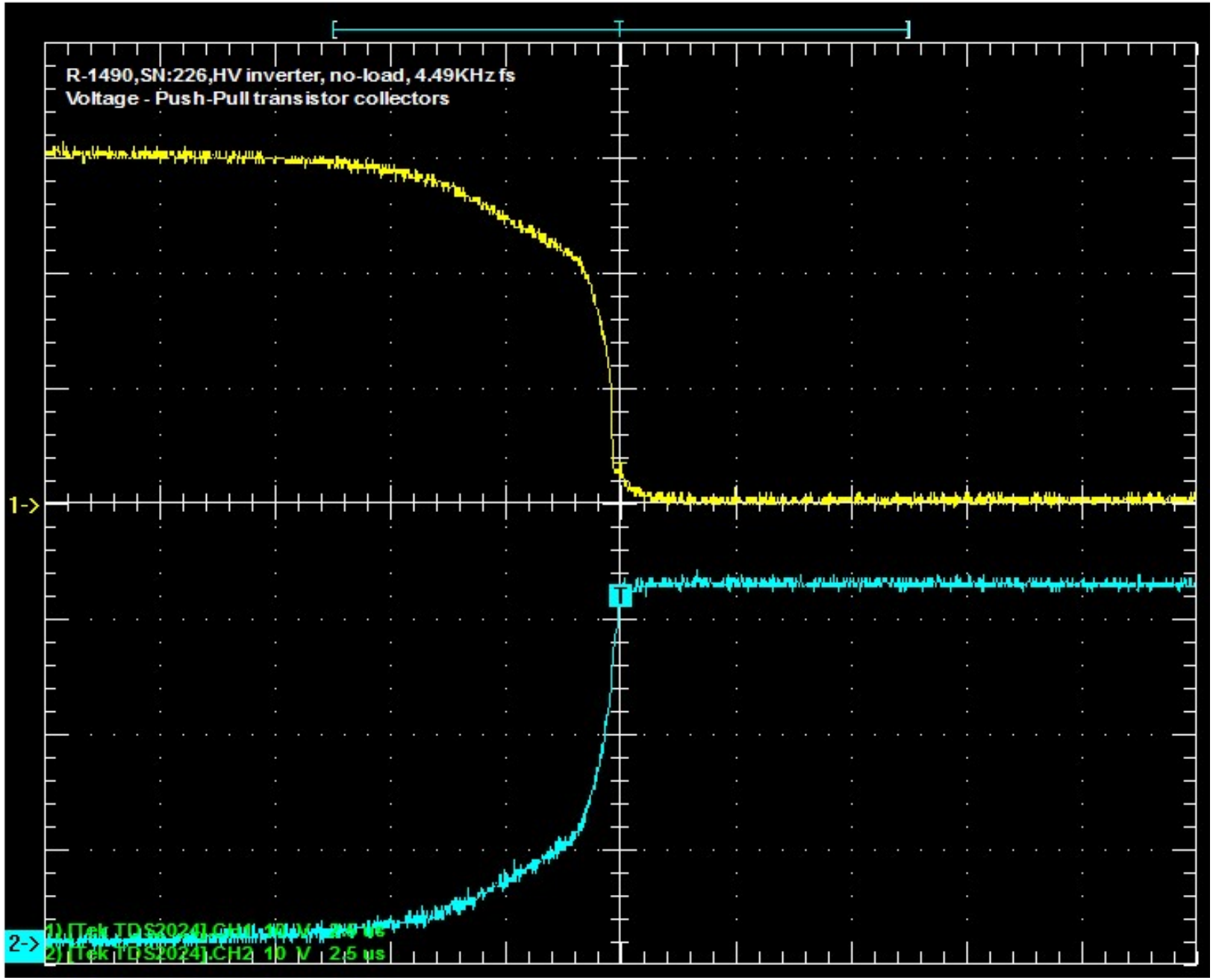
US military R-1490 receiver high voltage DC-DC module replacement/rebuild

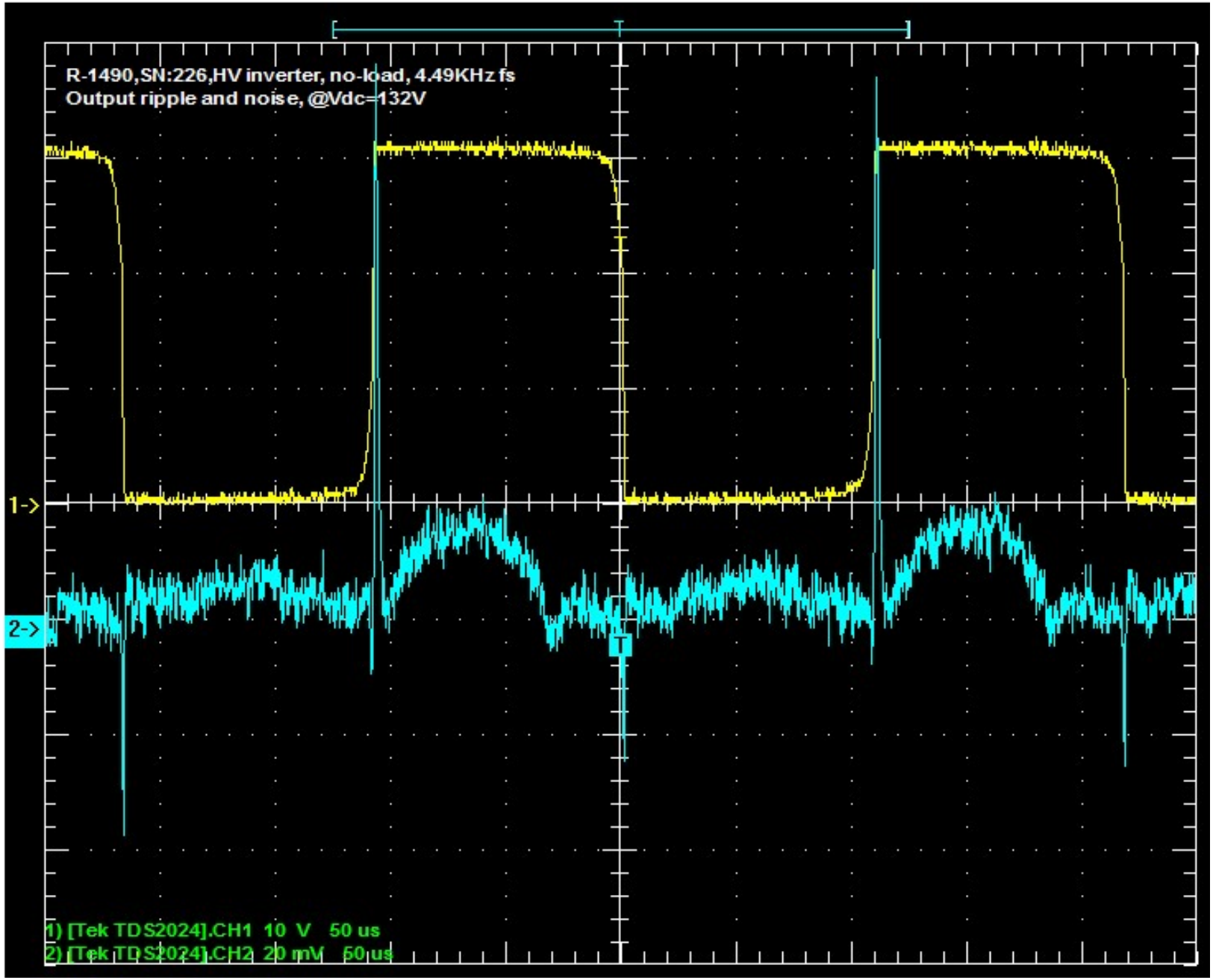
R-1490 original 125V DCDC converter waveforms

30-May-2011, Virgil Cheng, vr2xgm

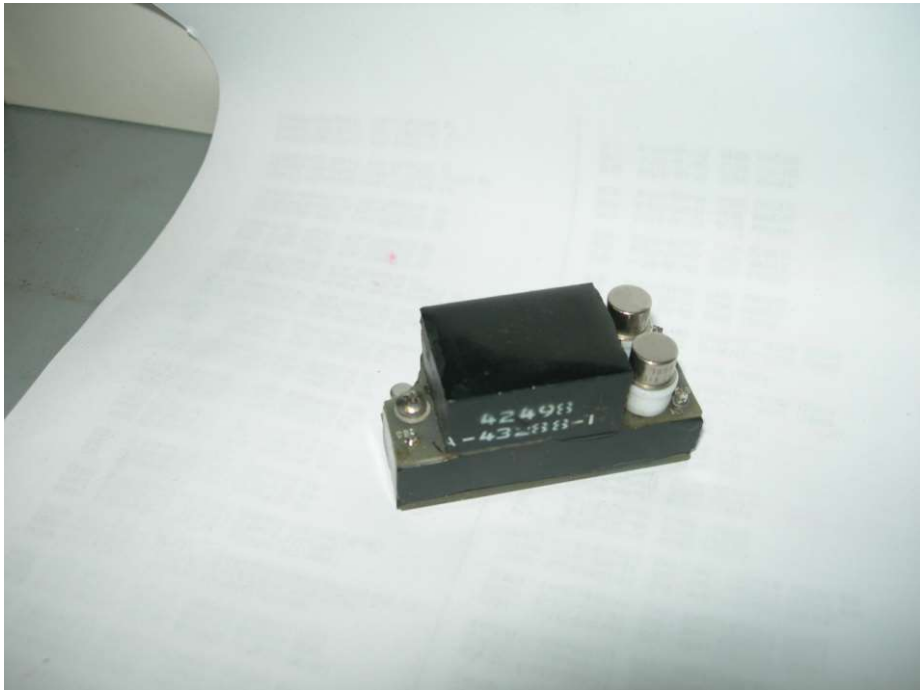

R-1490,SN:226,HV inverter, no-load, 4.49KHz fs
Voltage - Push-Pull transistor collectors
1->
2->
T
1) [Tek TDS2024].CH1 10 V 50 us


R-1490,SN:226,HV inverter, no-load, 4.49KHz fs
Voltage - Push-Pull transistor collectors
1->
2->
1) [Tek TDS2024].CH1 10 V 2.5 us
2) [Tek TDS2024].CH2 10 V 2.5 us

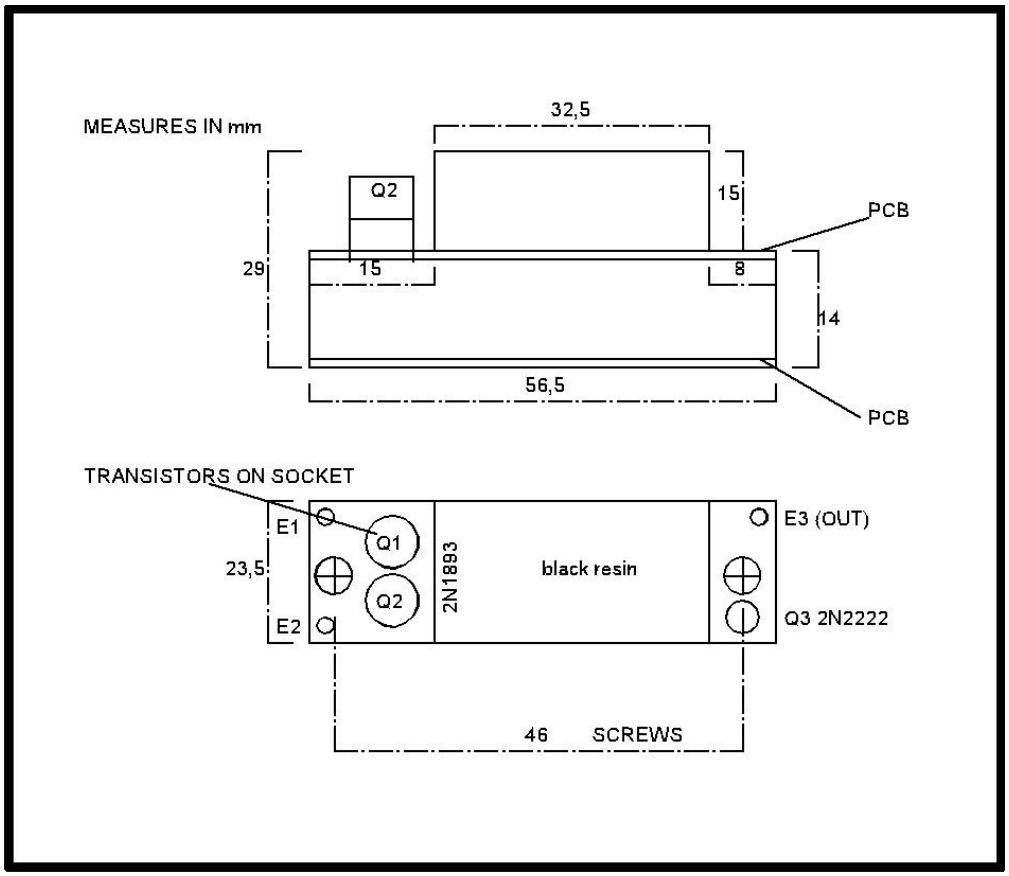

R-1490,SN:226,HV inverter, no-load, 4.49KHz fs
Voltage - Push-Pull transistor collectors
1->
2->
2] [Tek TDS2024] CH2 10 V 2.5 us


R-1490,SN:226,HV inverter, no-load, 4.49KHz fs
Output ripple and noise, @Vdc=132V
1->
2->
1) [Tek TDS2024].CH1 10 V 50 us
2) [Tek TDS2024].CH2 20 mV 50 us

Photos- Original R-1490 inverter module, courtesy Valter Corda IZ0NHT

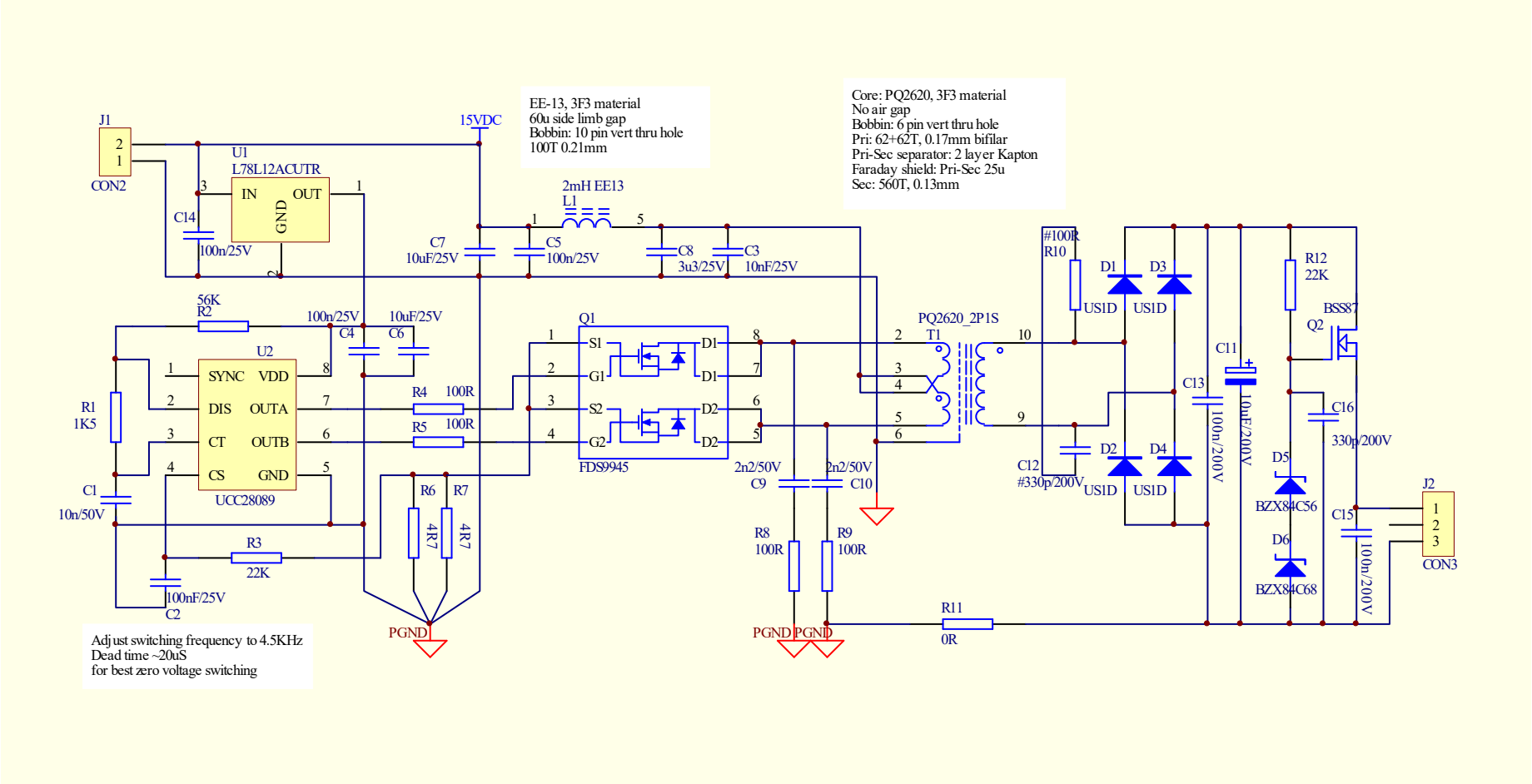


Dimension original R-1490 inverter module, , courtesy Valter Corda IZ0NHT



R-1490 125V DCDC converter rebuilt
28-Jun-2016, Virgil Cheng, vr2xgm

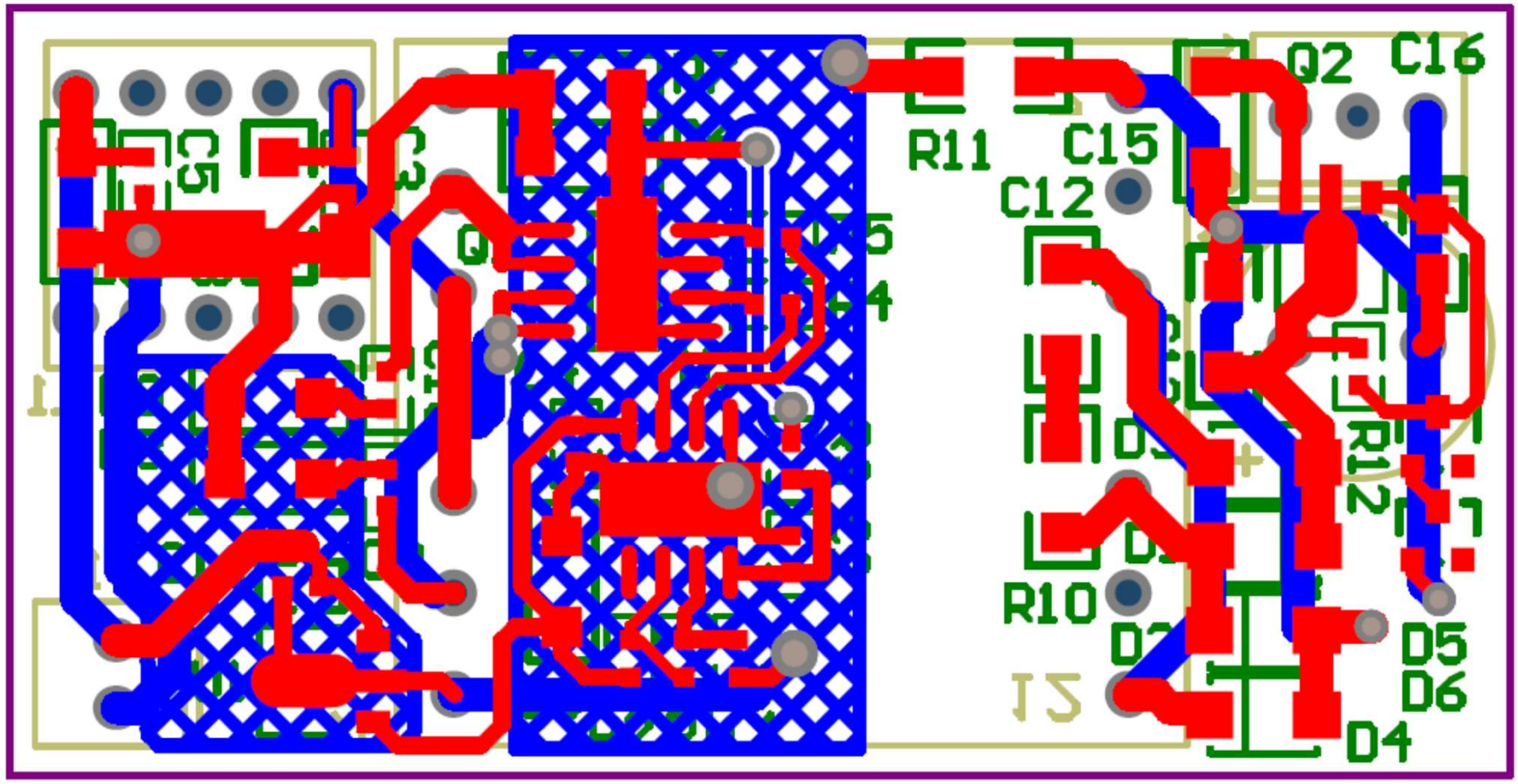
Schematic, resonant push-pull converter, rev 0.0



This in fact is more complicated than original two transistor circuit, I took this opportunity to experiment with prior-art resonant push-pull topology, its soft-switching characteristic gives good noise performance

PCB, resonant push-pull converter, Rev. 0.0

Laminate: FR4, 1.6mm, 2 Oz Cu
Dim: W29mm, L56.3mm



Bill of material, resonant push-pull converter

Legend	Description
C1	Cap, ceramic, 10n, 50V, 5%, X7R, 0603
C2	Cap, ceramic, 100n, 25V, 10%, X7R, 0603
C3	Cap, ceramic, 10n, 25V, 5%, X7R, 0603
C4	Cap, ceramic, 100n, 25V, 10%, X7R, 0603
C5	Cap, ceramic, 100n, 25V, 10%, X7R, 0603
C6	Cap, ceramic, 10u, 25V, 10%, X5R, 1206
C7	Cap, ceramic, 10u, 25V, 10%, X5R, 1206
C8	Cap, ceramic, 3u3, 25V, 10%, X7R, 1206
C9	Cap, ceramic, 2n2, 25V, 5%, X7R, 0603
C10	Cap, ceramic, 2n2, 25V, 5%, X7R, 0603
C11	Cap, Elec, 10uF, 160V, 105C
C12	Not populated
C13	Cap, ceramic, 100n, 200V, 10%, X7R, 1206
C14	Cap, ceramic, 100n, 25V, 10%, X7R, 0603
C15	Cap, ceramic, 100n, 200V, 10%, X7R, 1206
C16	Cap, ceramic, 330p, 200V, 10%, C0G, 0805
D1	Diode , Ultrafast, 1A, 200V, SMA, US1D
D2	Diode , Ultrafast, 1A, 200V, SMA, US1D
D3	Diode , Ultrafast, 1A, 200V, SMA, US1D
D4	Diode , Ultrafast, 1A, 200V, SMA, US1D
D5	Diode, Zener, 56V, SOT-23, BZX84C56
D6	Diode, Zener, 68V, SOT-23, BZX84C68

Bill of material, resonant push-pull converter

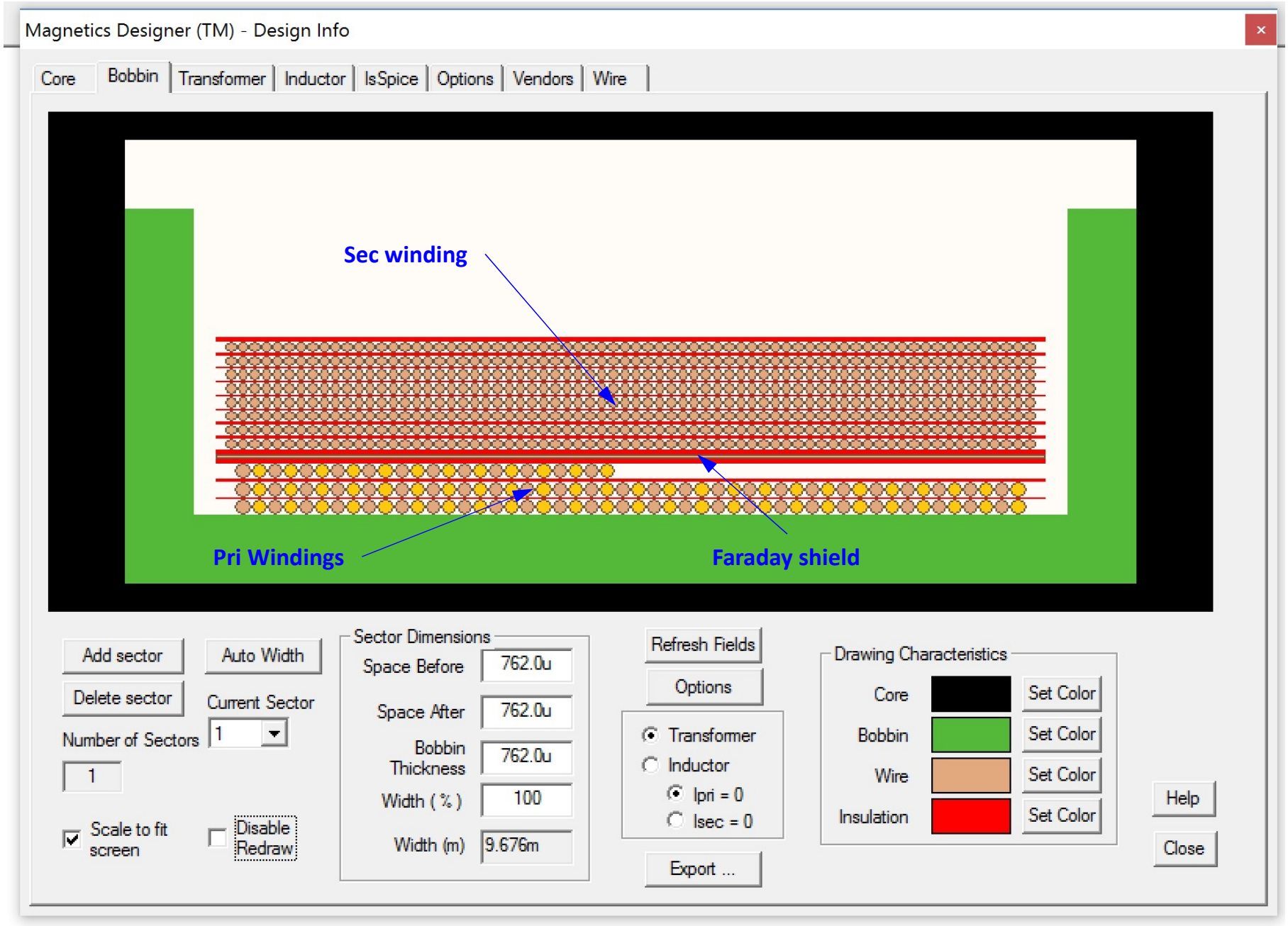
Legend	Description
J1	Header , 2pin, 0.1”, Molex 6410 series
J2	Header , 3pin, 0.1”, Molex 6410 series
L1	Choke, 2mH, EE-13, thru hole
Q1	MOSFET-N, Dual, 60V, 3A5, 0R1, SO-8, FDS9945
Q2	MOSFET-N, 200V 0A4, 3R, SOT-89, BSS87
R1	Res, CF, 1K5, 5%, 0W125, 0603
R2	Res, CF, 56K, 5%, 0W125, 0603
R3	Res, CF, 22K, 5%, 0W125, 0603
R4	Res, CF, 100R, 5%, 0W125, 0603
R5	Res, CF, 100R, 5%, 0W125, 0603
R6	Res, CF, 4R7, 5%, 0W25, 1206
R7	Res, CF, 4R7, 5%, 0W25, 1206
R8	Res, CF, 100R, 5%, 0W25, 1206
R9	Res, CF, 100R, 5%, 0W25, 1206
R10	Not populated
R11	Res, CF, 0R, 5%, 0W25, 1206
R12	Res, CF, 22K, 5%, 0W125, 0603
T1	Transformer, PQ2620, 62Tx2:560T
U1	Regulator, Linear, 3T, LDO, SOT-89, L78L12ACUTR
U2	IC, PWM, UCC28089

Summary transformer T1

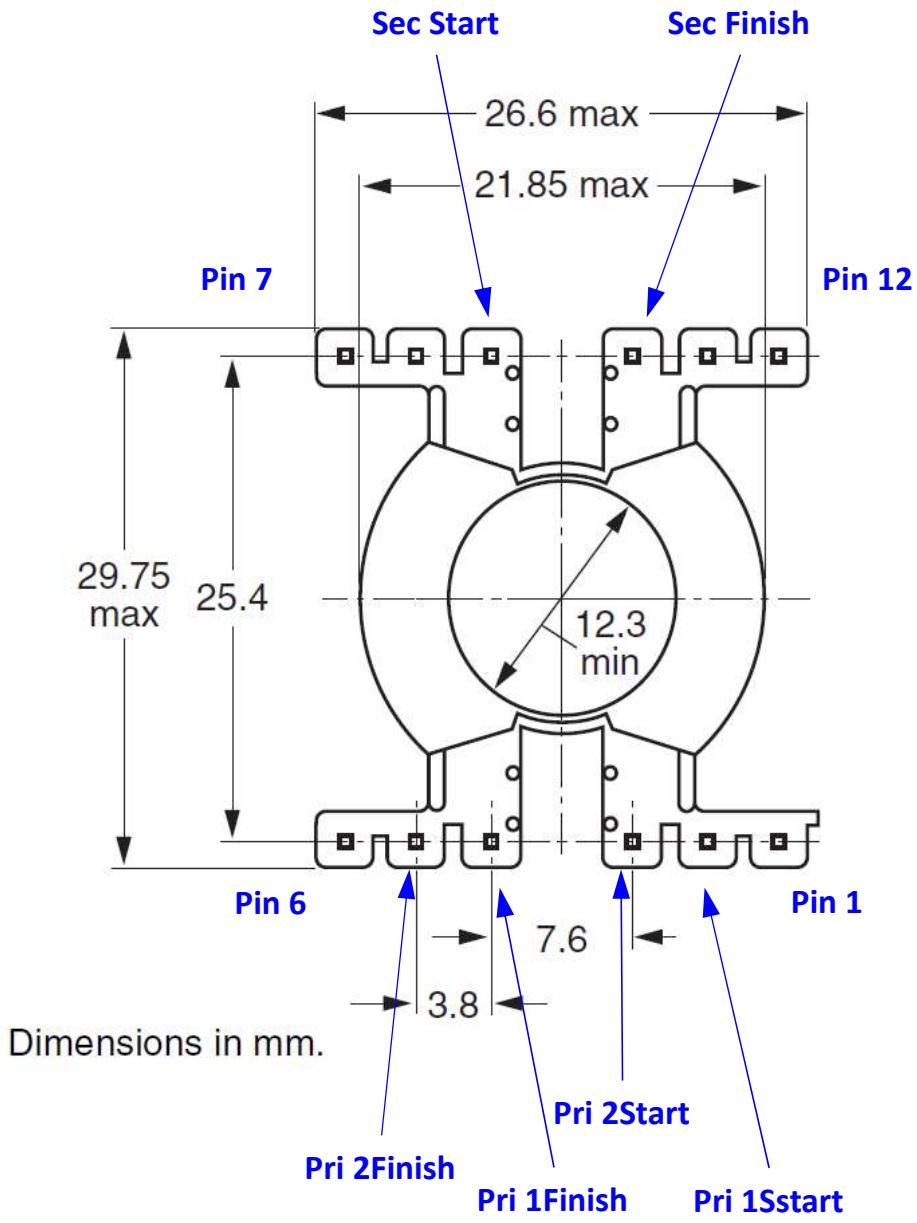
Core geometry	PQ2620	
Core material	Ferroxcube 3F3 or similar	
Gap	None	
Primary	62+62T Bifilar, ϕ0.17mm, double coat	
Pri-Sec Faraday shield	1T, 25um Cu	
Secondary	560T, ϕ0.13mm, double coat	
Finish	Varnish dip	
Inductance primary	18mH typical	
Leakage inductance	20uH typical, sec short, primary open	
DC resistance primary	2.5Ω typ.	
DC resistance secondary	42.1Ω typ.	
Breakdown test	Pri-sec 300V AC	

Steel is more suitable than ferrite for 4.5KHz switching frequency, requires large number of turns for flux density criteria, only reason is core/bobbin availability and windings can still fit bobbin

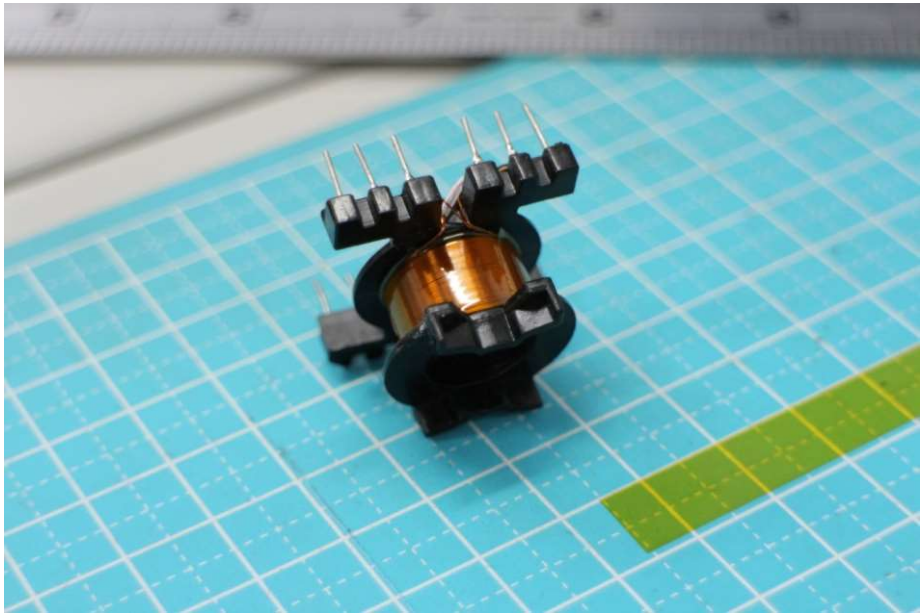
Transformer Cross-section

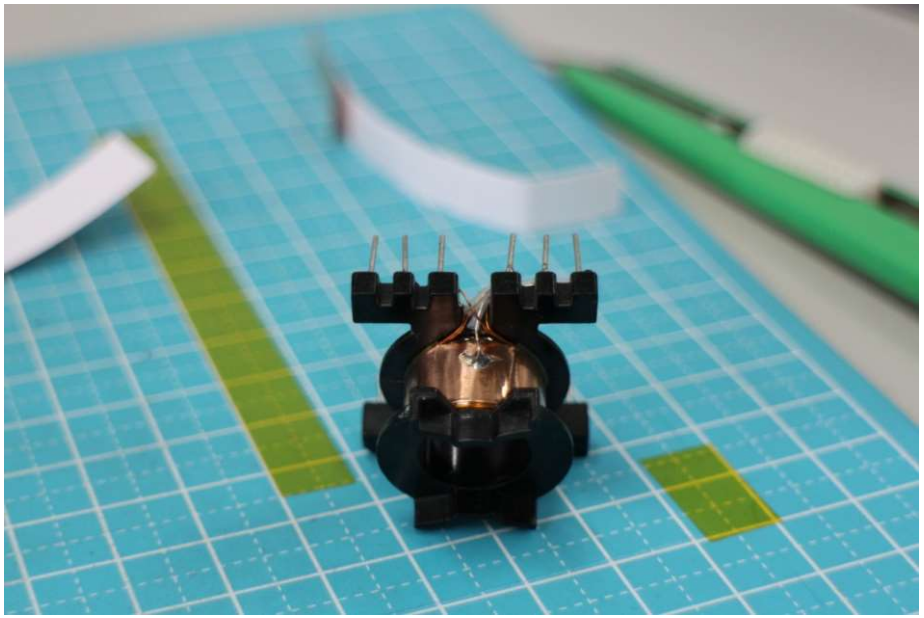


Transformer pinout, bottom view



Transformer

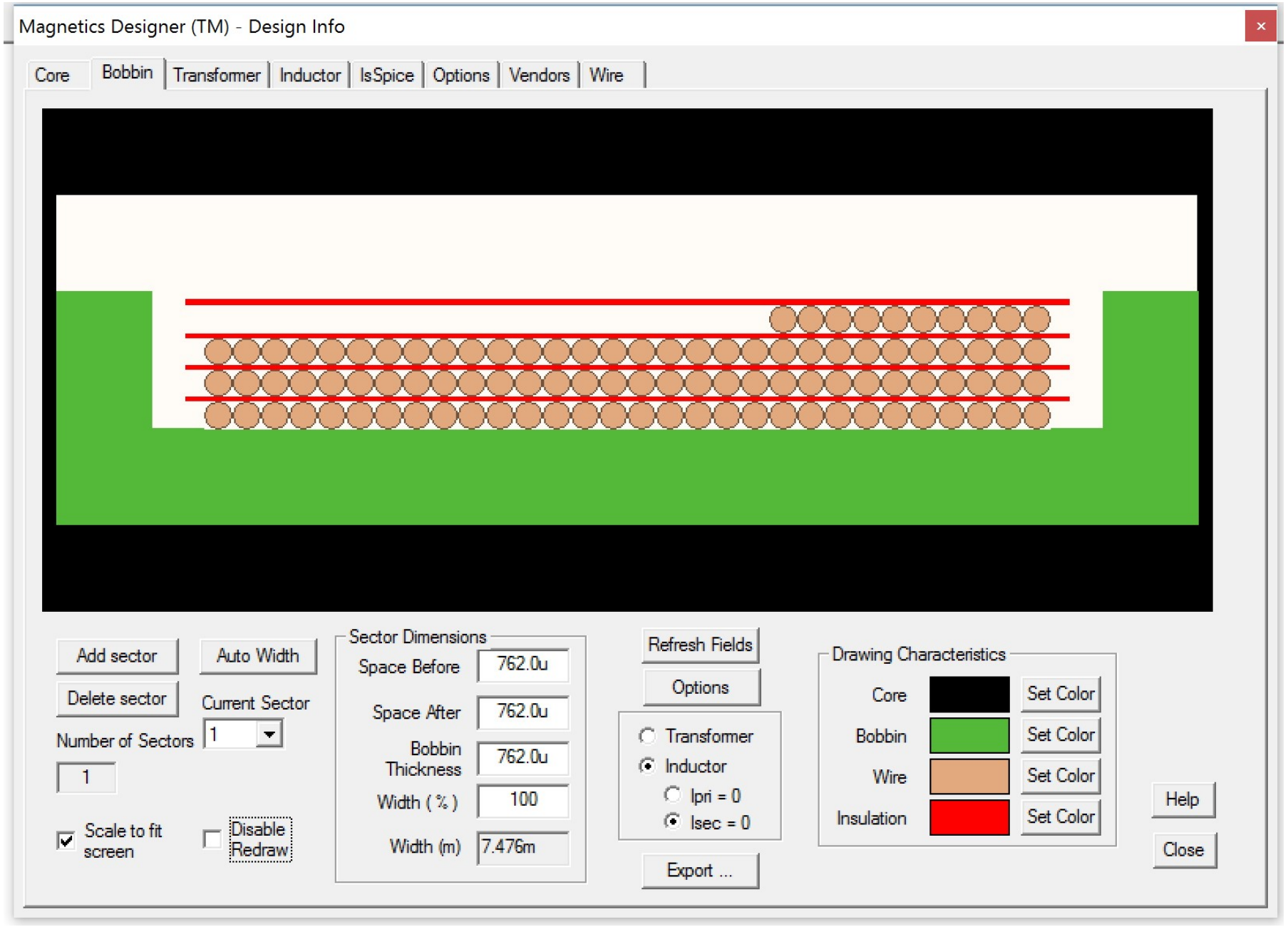




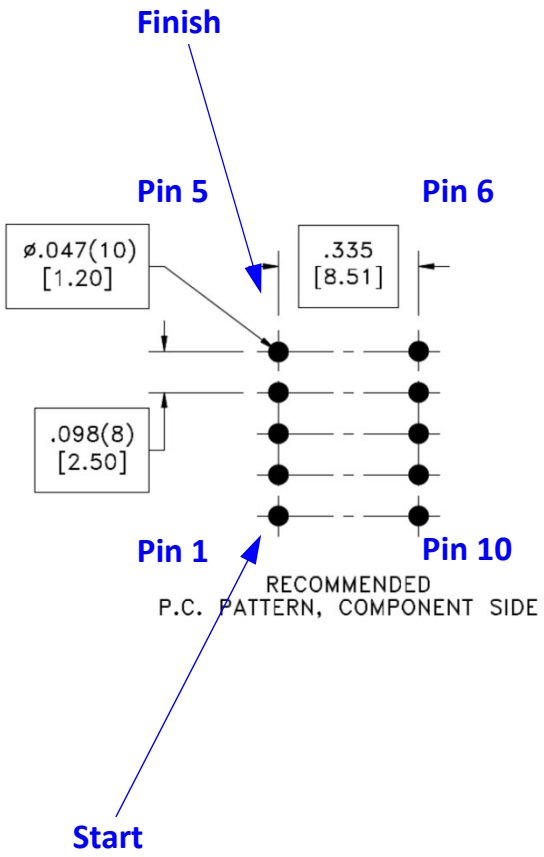
Summary Inductor L1

Core geometry	EE13/6/6	
Core material	Ferroxcube 3F3 or similar	
Gap	0.06mm side limbs	
Primary	100T, ϕ0.21mm	
Pri-Sec Faraday shield	N/A	
Secondary	N/A	
Finish	Varnish dip	
Inductance primary	2mH typ.	
Leakage inductance	N/A	
DC resistance primary	0.6Ω typ.	
DC resistance secondary	N/A	
Breakdown test	N/A	

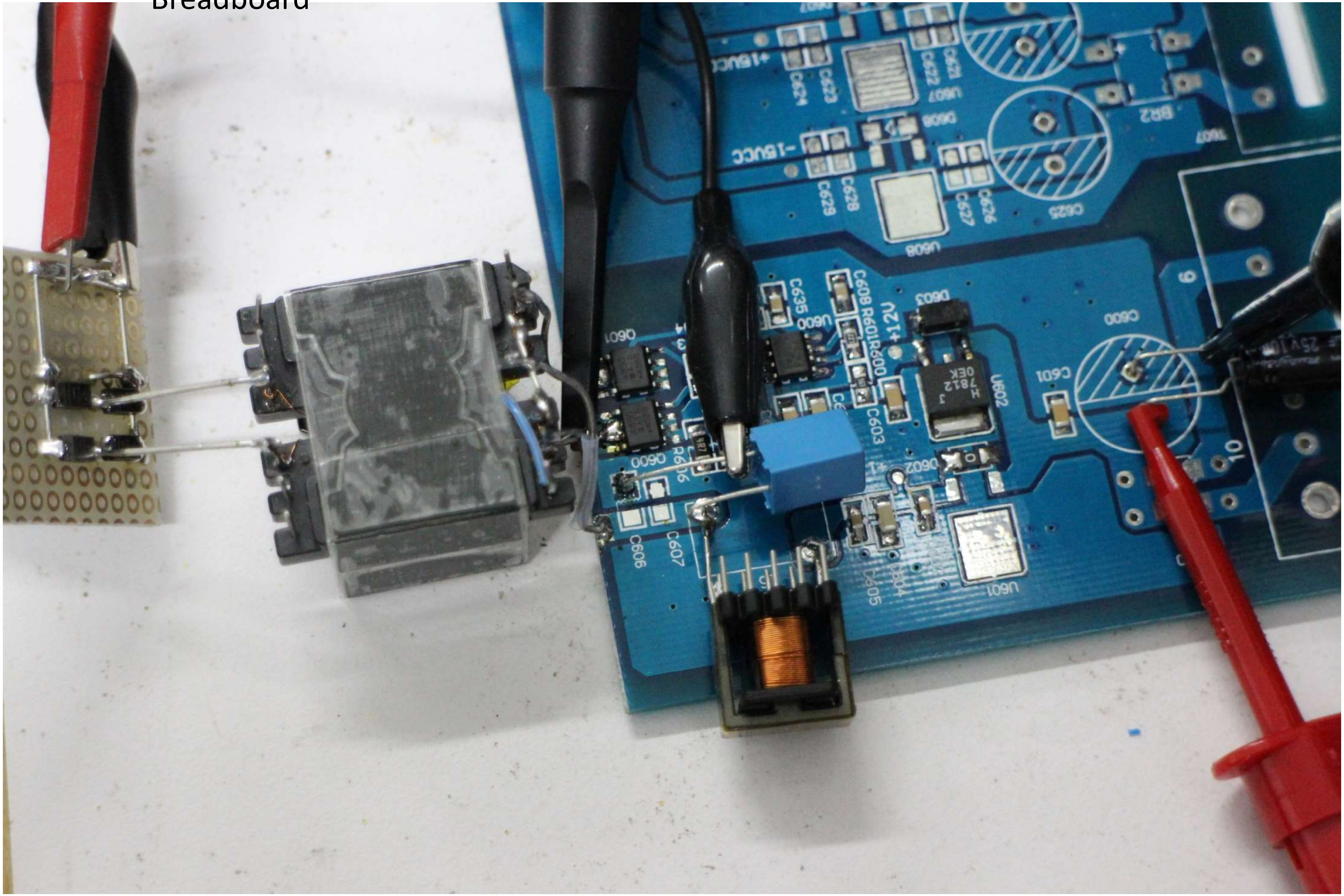
Inductor Cross-section



Inductor pinout, bottom view

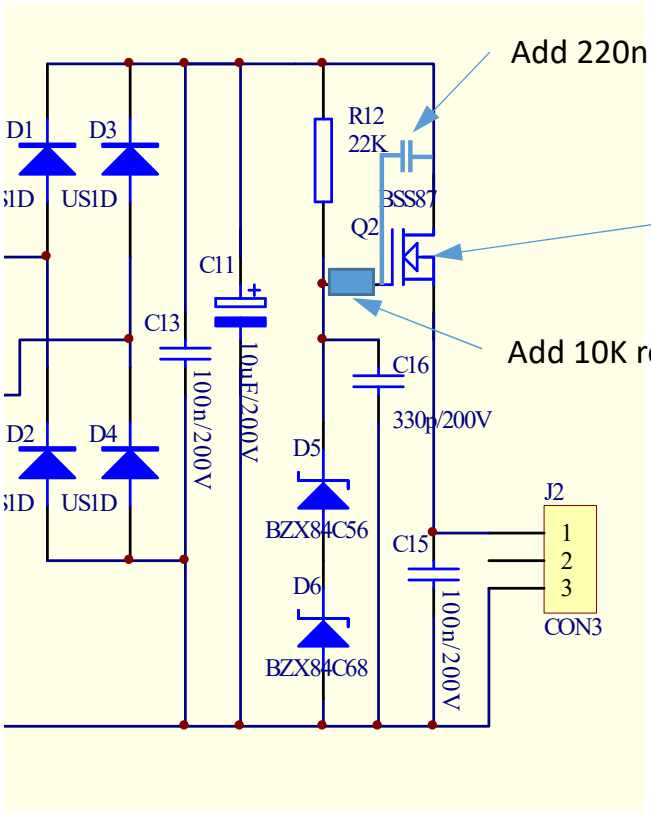


Breadboard

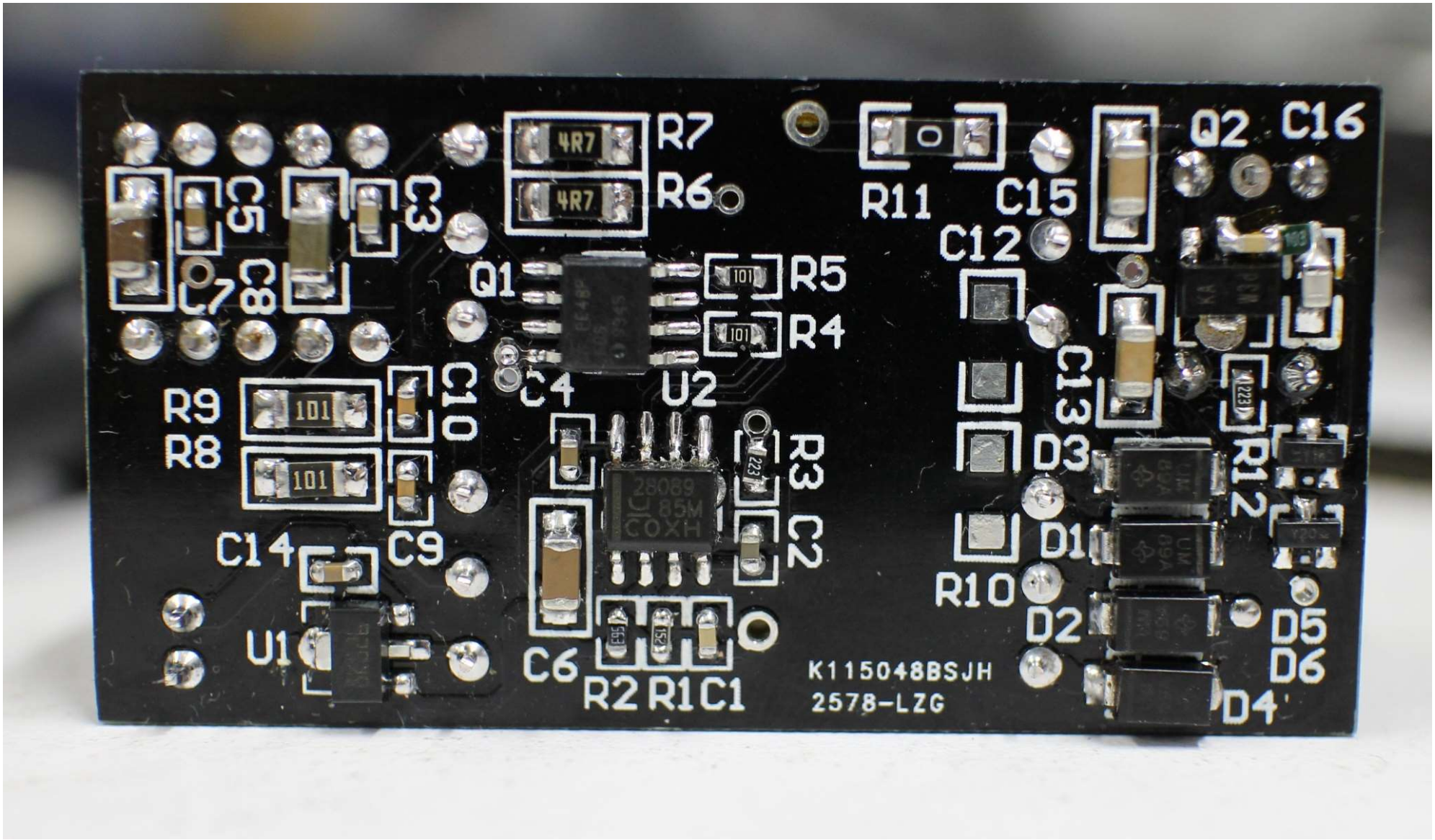


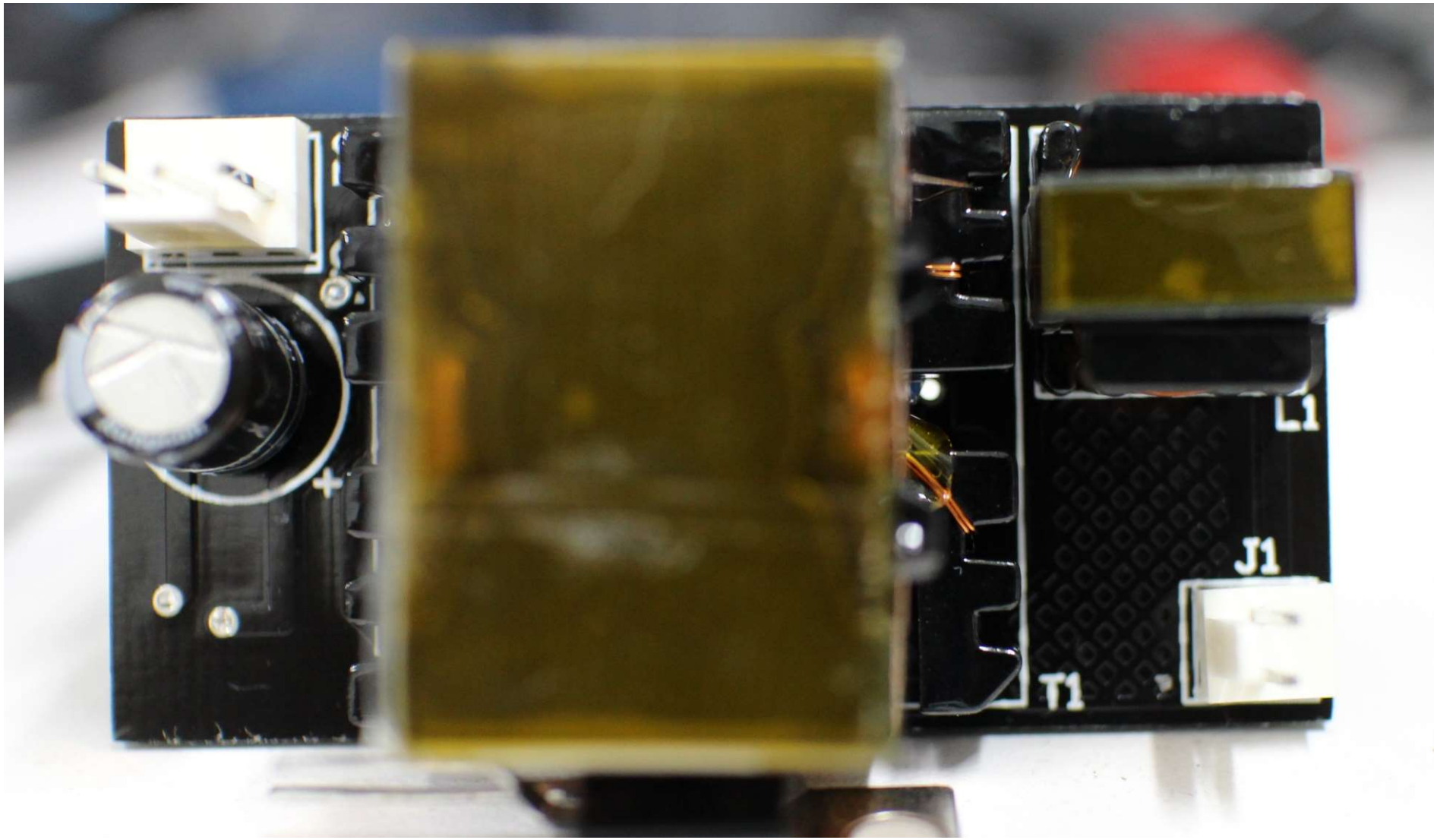
Debugging: Linear regulator parasitic oscillation suppression

Q2 fails easily when output shorts. De-populate Q2,D5,D6.R12,C16 and connect Drain/Source pad of Q2 if improved regulation is not needed

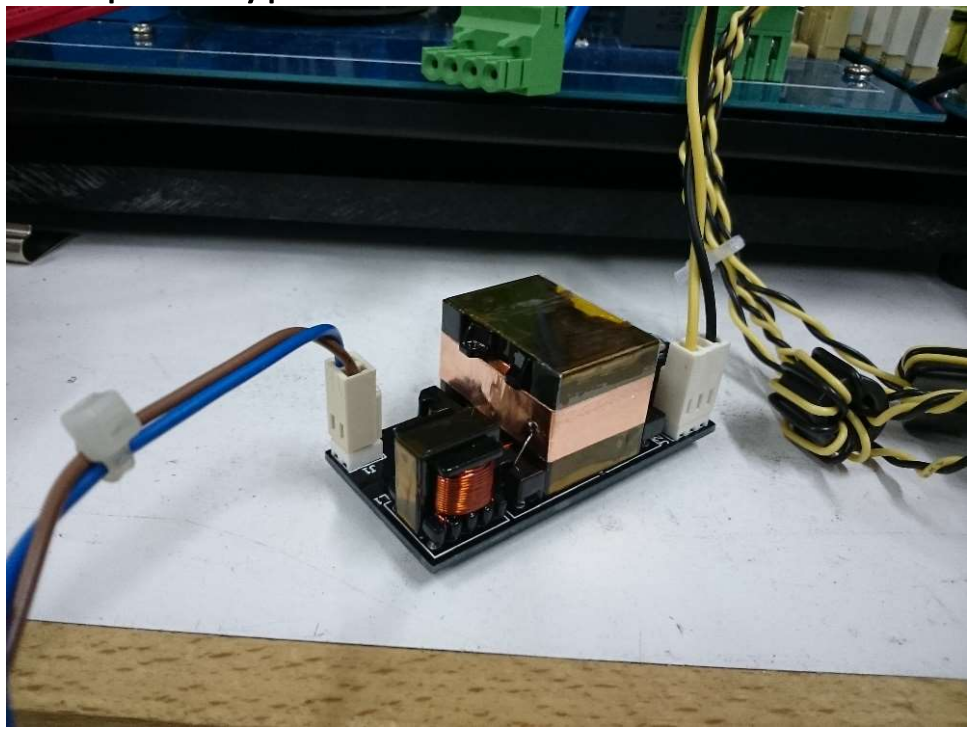


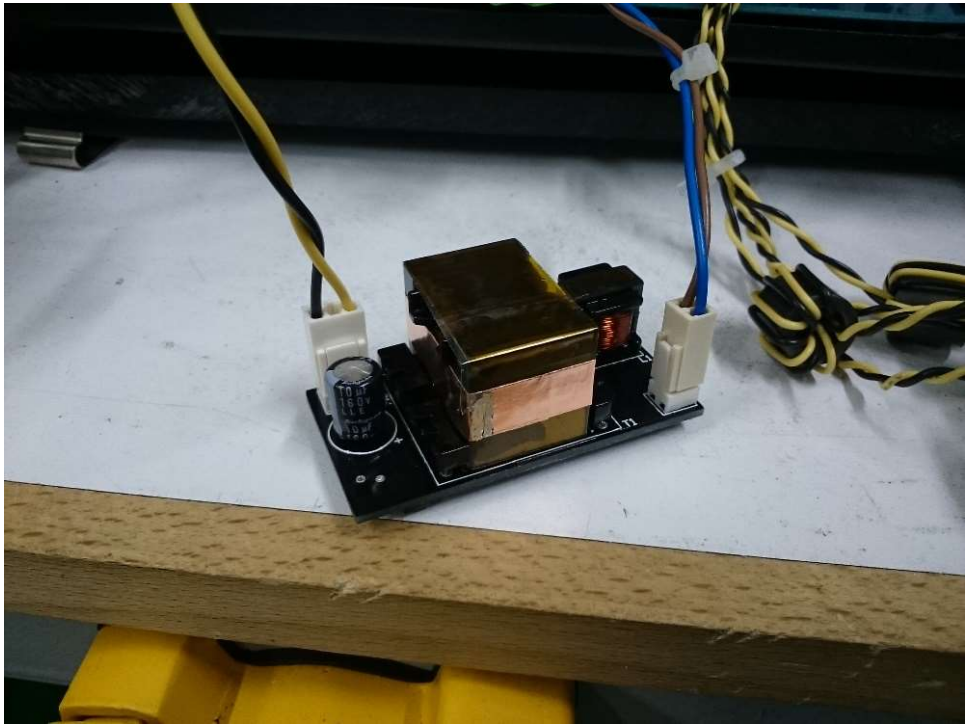
Alternative method:
Replace Q2 with NPN bipolar transistor like MPSA42, 10K resistor and 220n capacitor are not necessary. (to be tested)

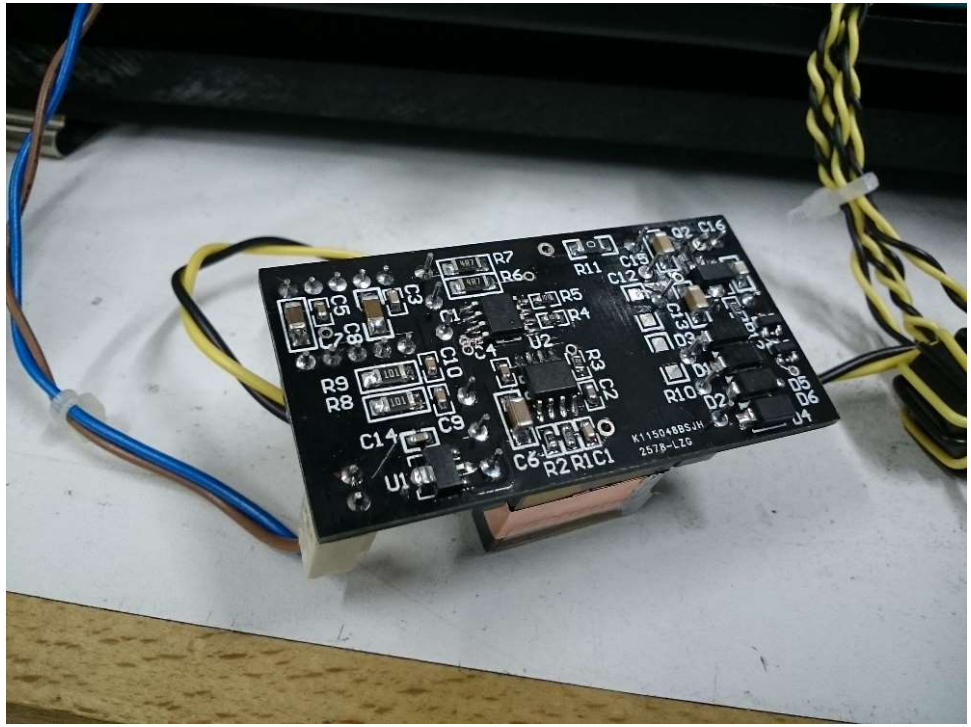

R7
R6
R11
C15
Q2
C16
C5
C3
C7
C8
Q1
R5
R4
C12
C4
U2
C13
R9
R8
C10
C9
C14
R3
C2
D3
R12
D1
R10
D2
D5
D6
D4
U1
C6
R2
R1
C1
K115048BSJH
2578-LZG


L1
J1
T1

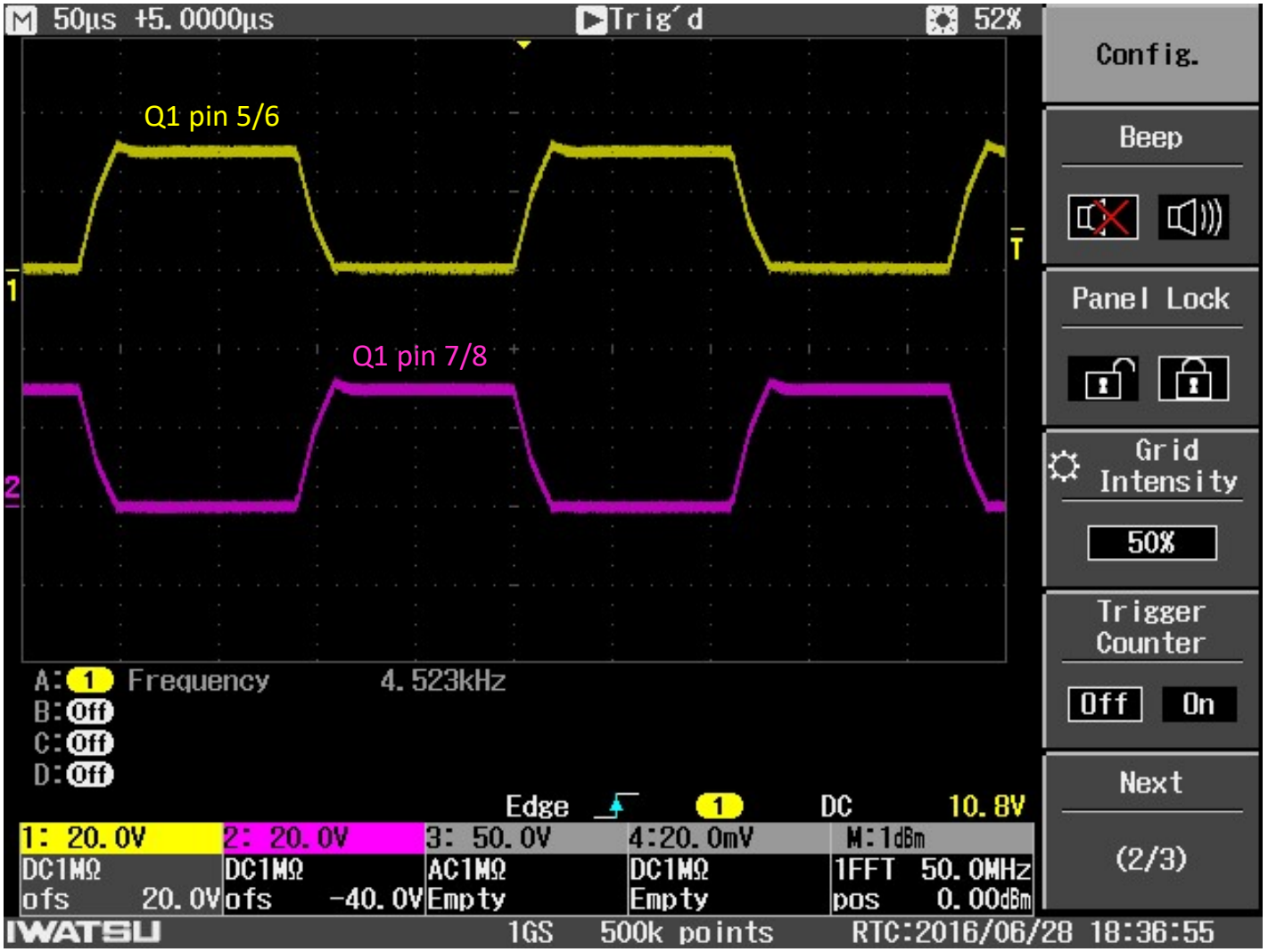
First prototype



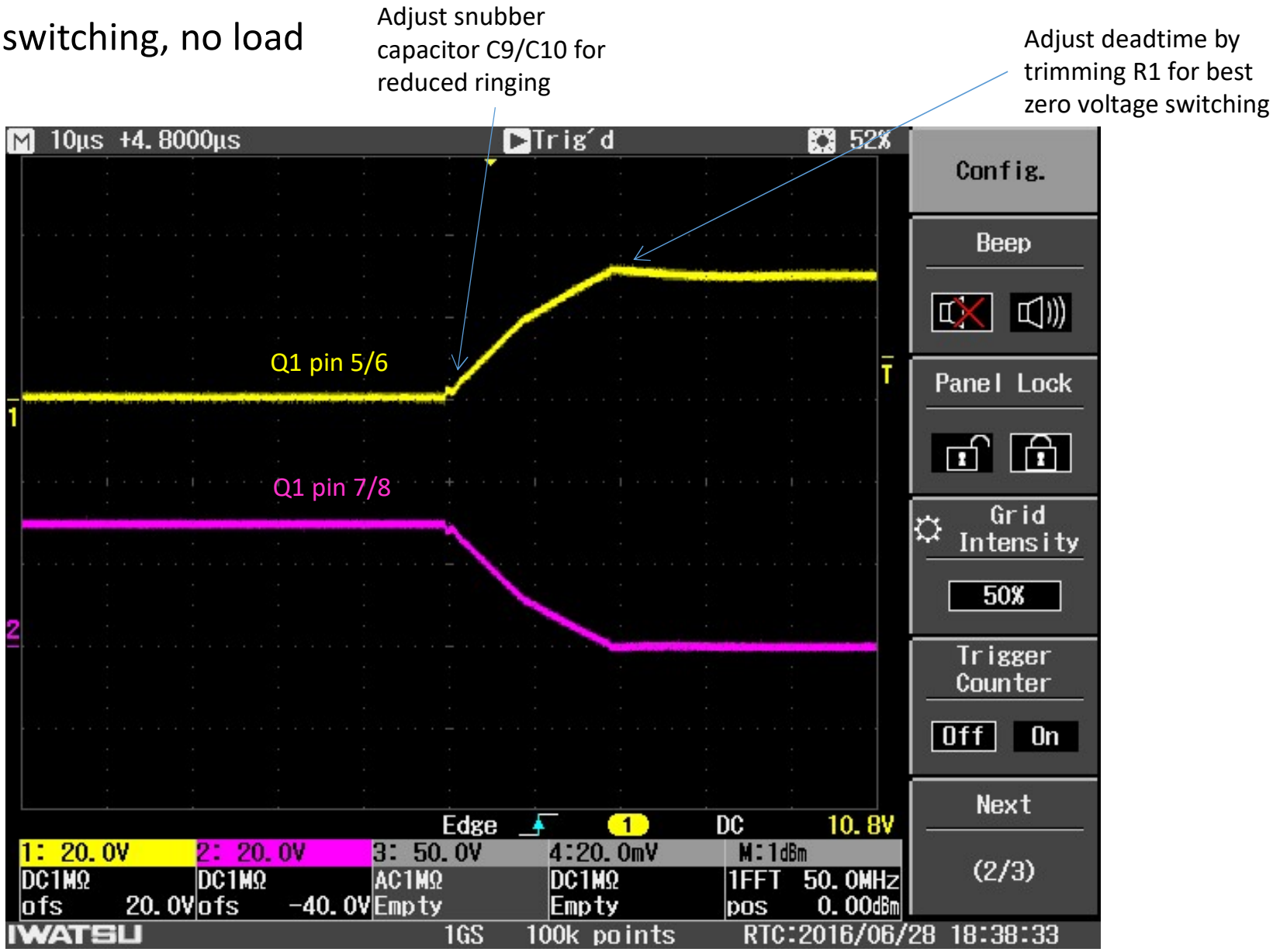




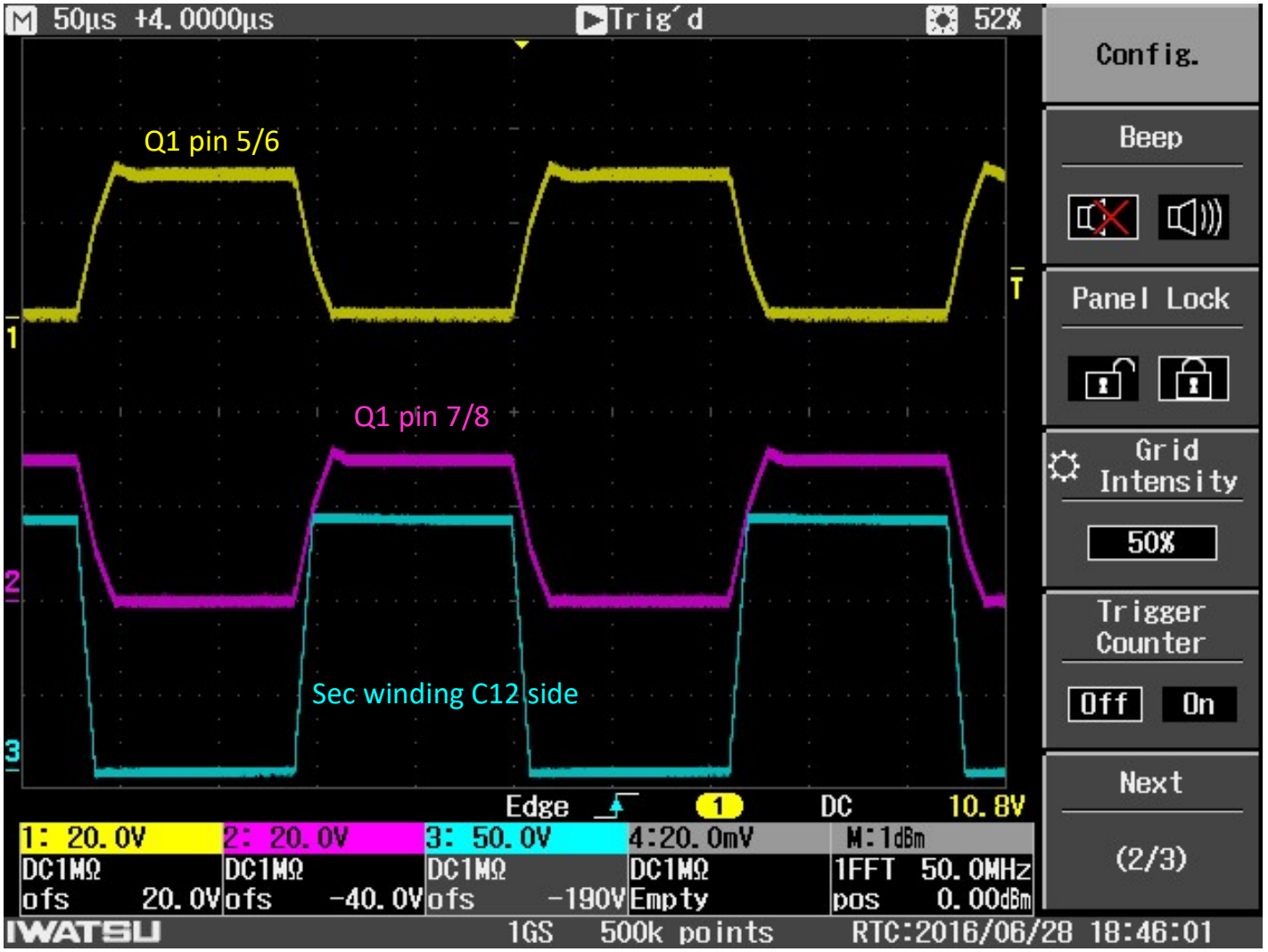
Waveform, switching, no load



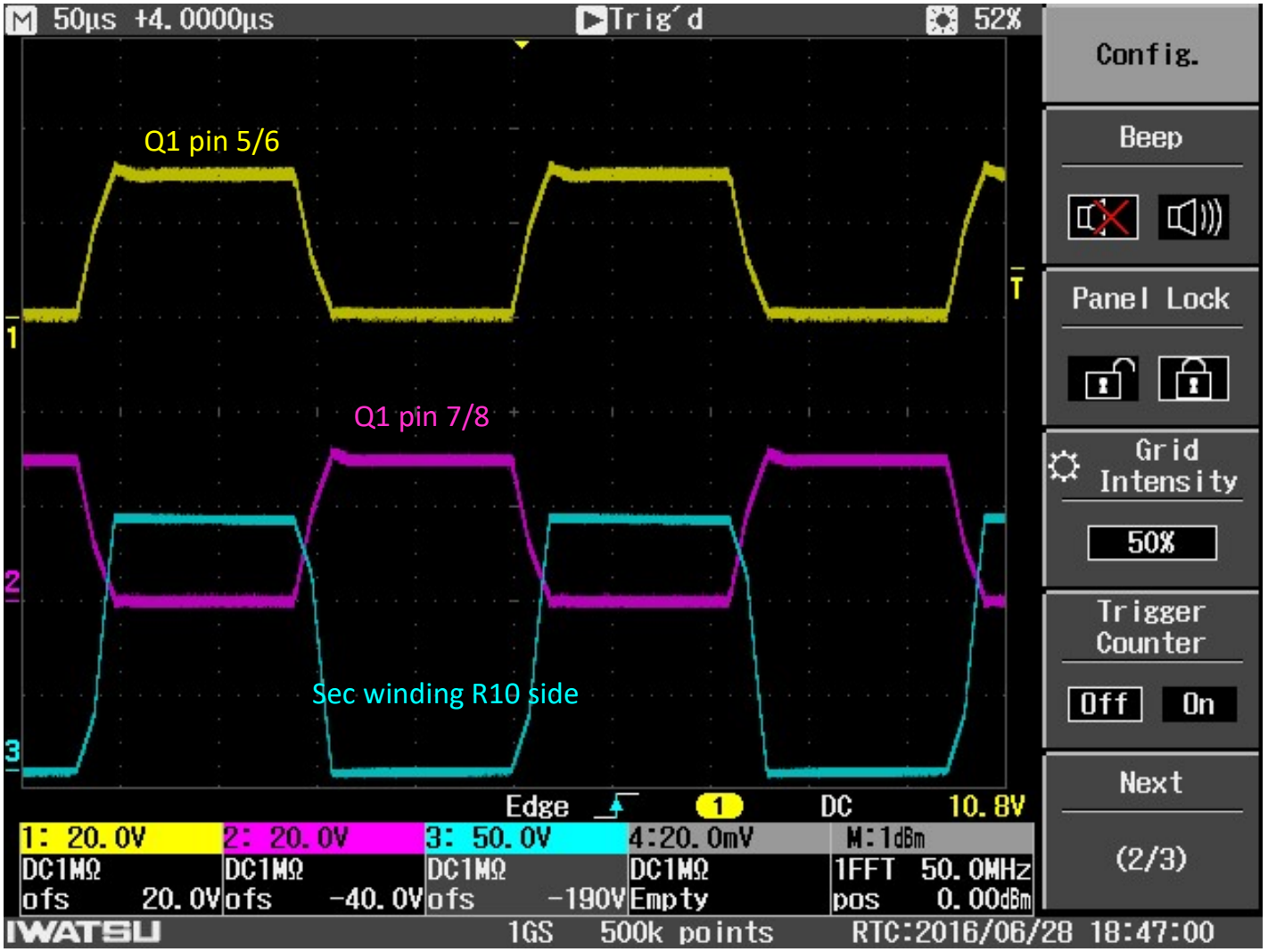
Waveform, switching, no load



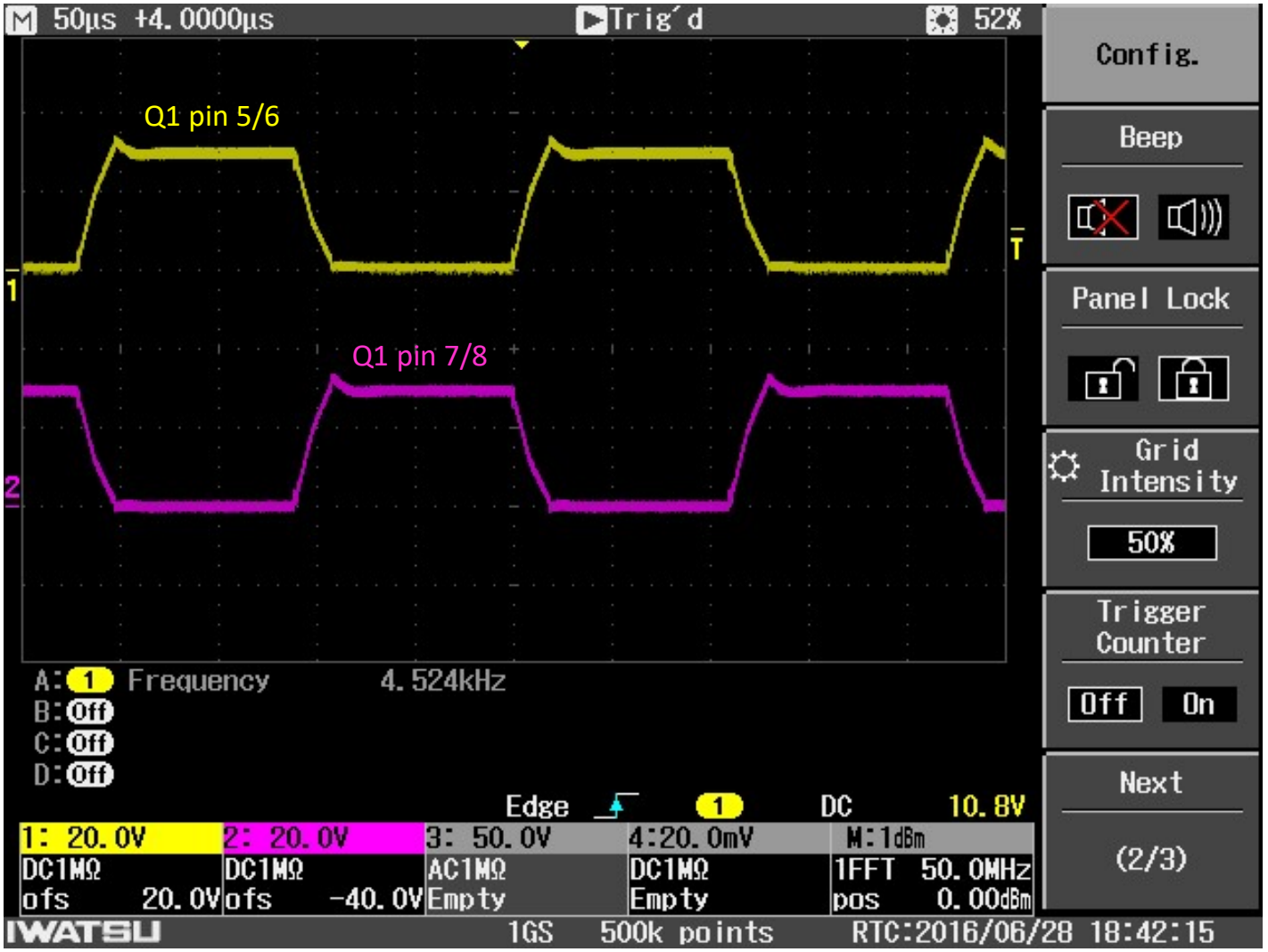
Waveform, switching, no load



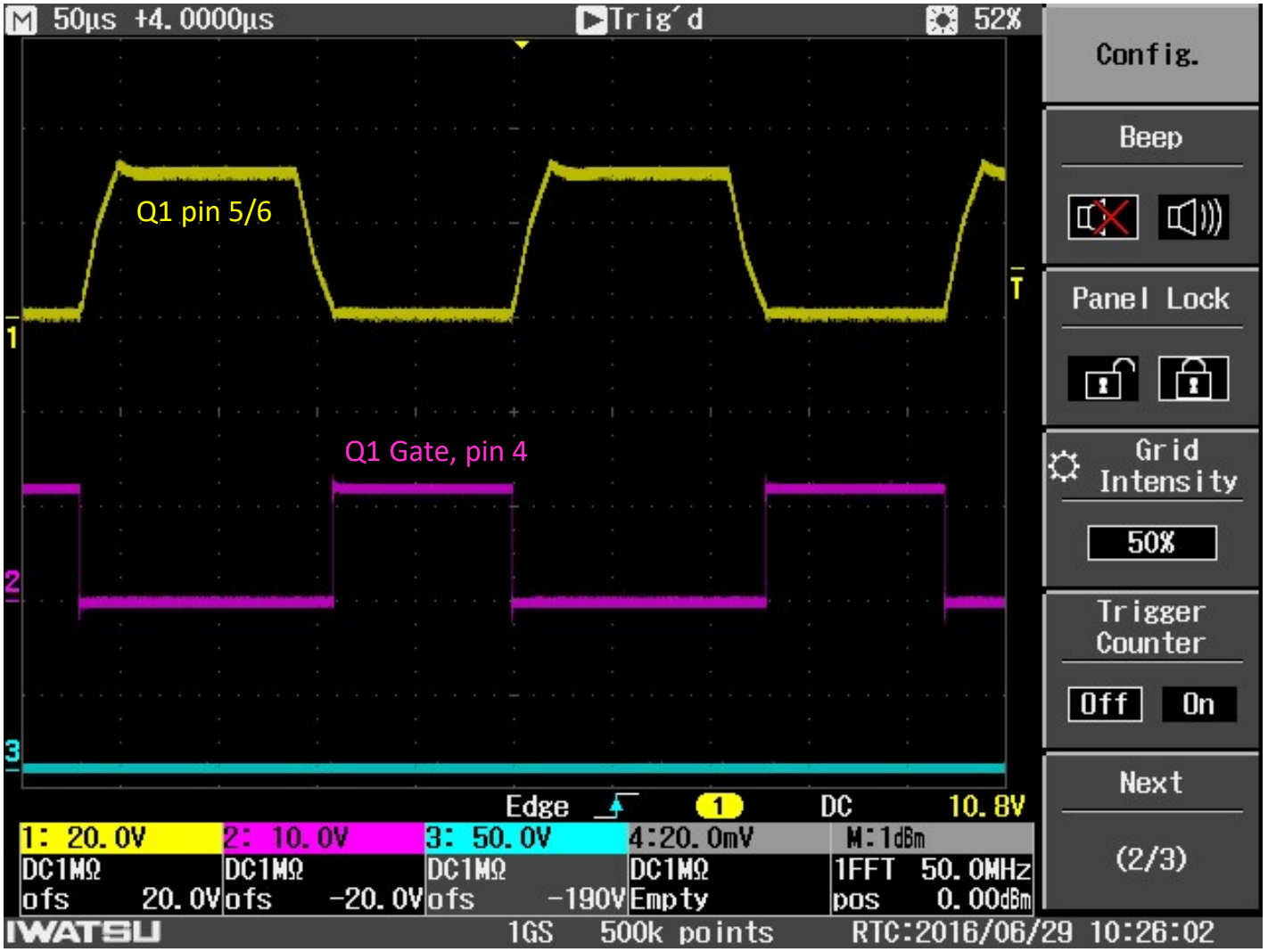
Waveform, switching, no load



Waveform, switching, 5mA

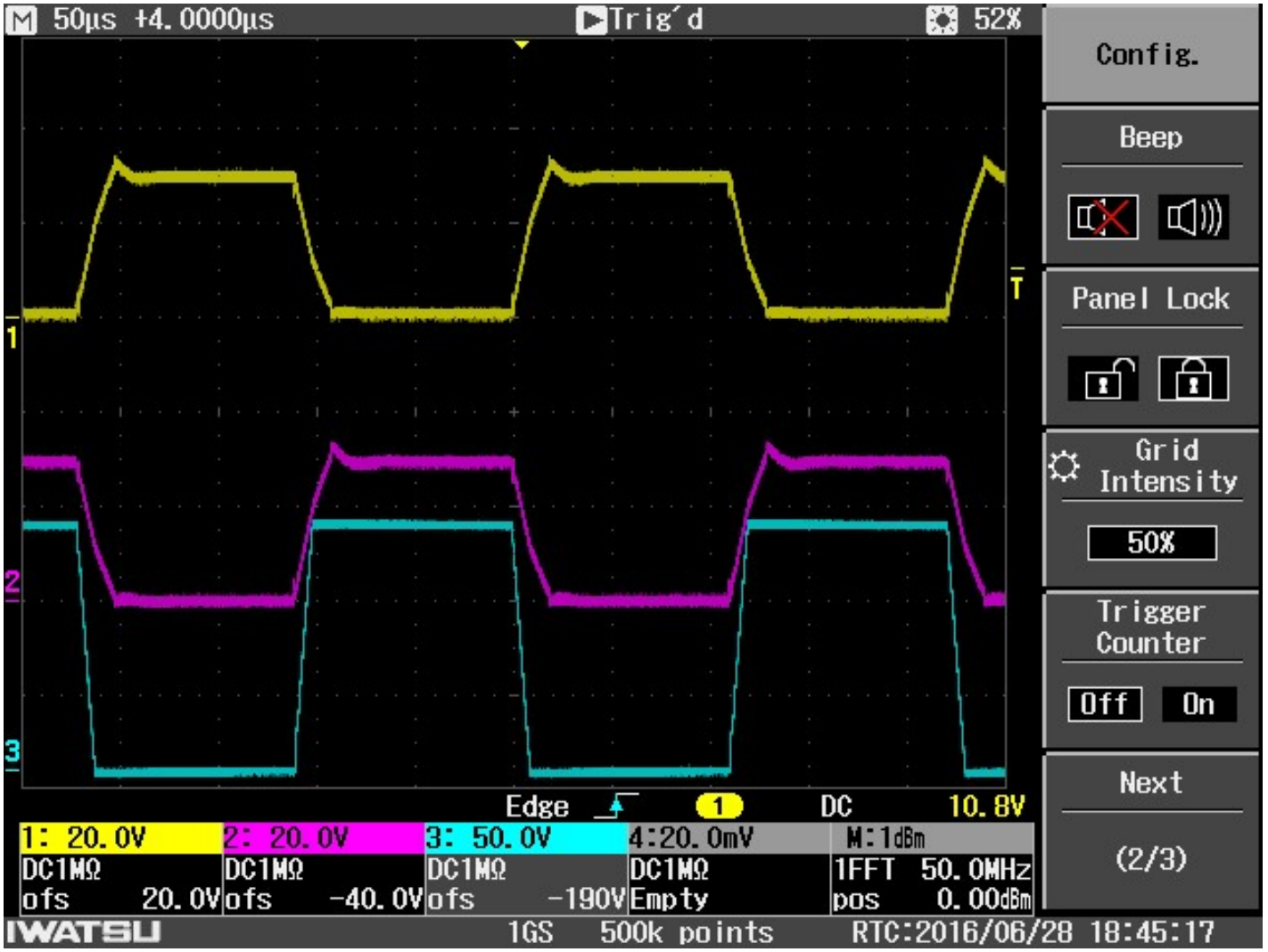


Waveform, switching, 5mA

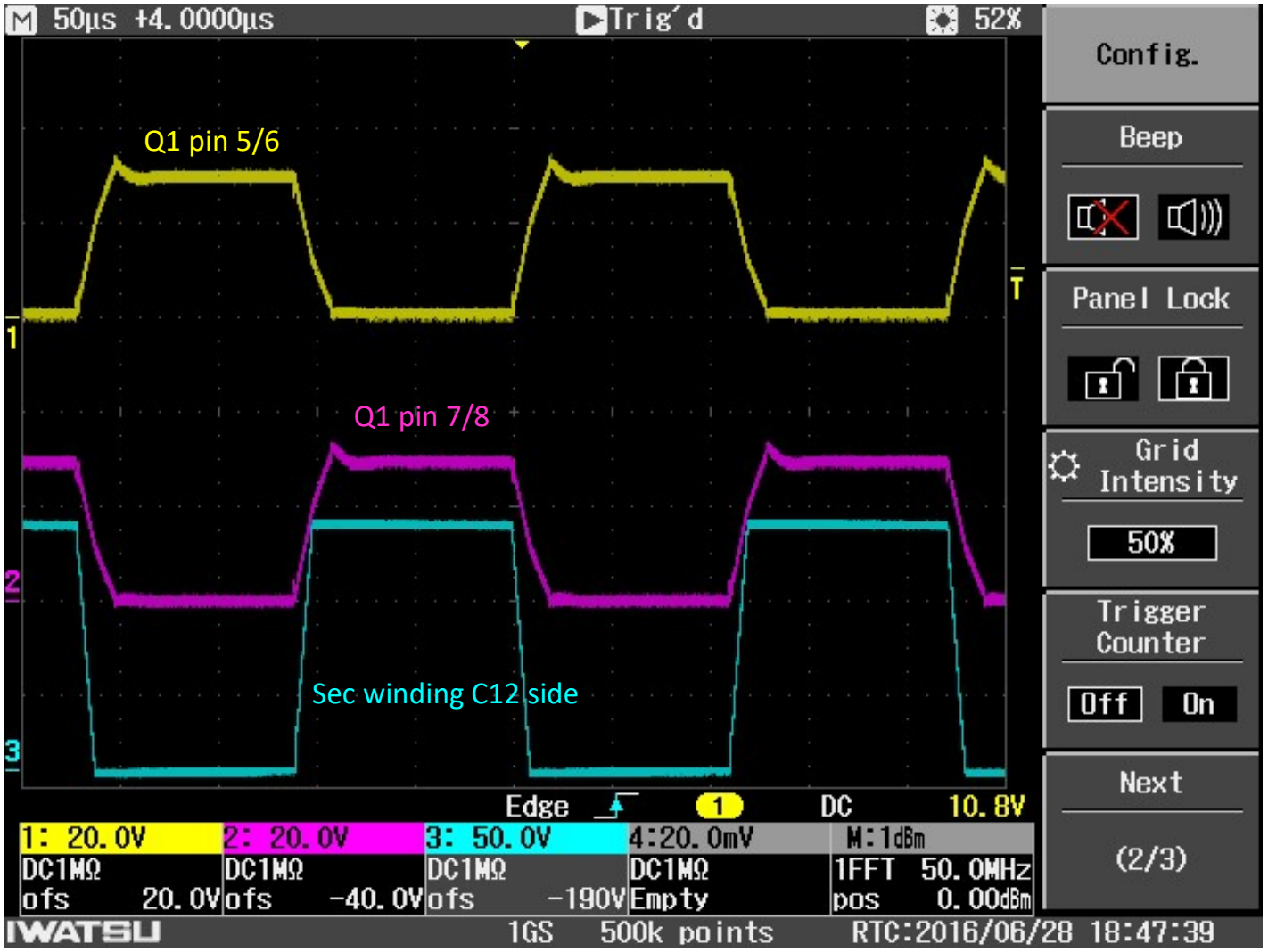


Waveform, switching, 5mA

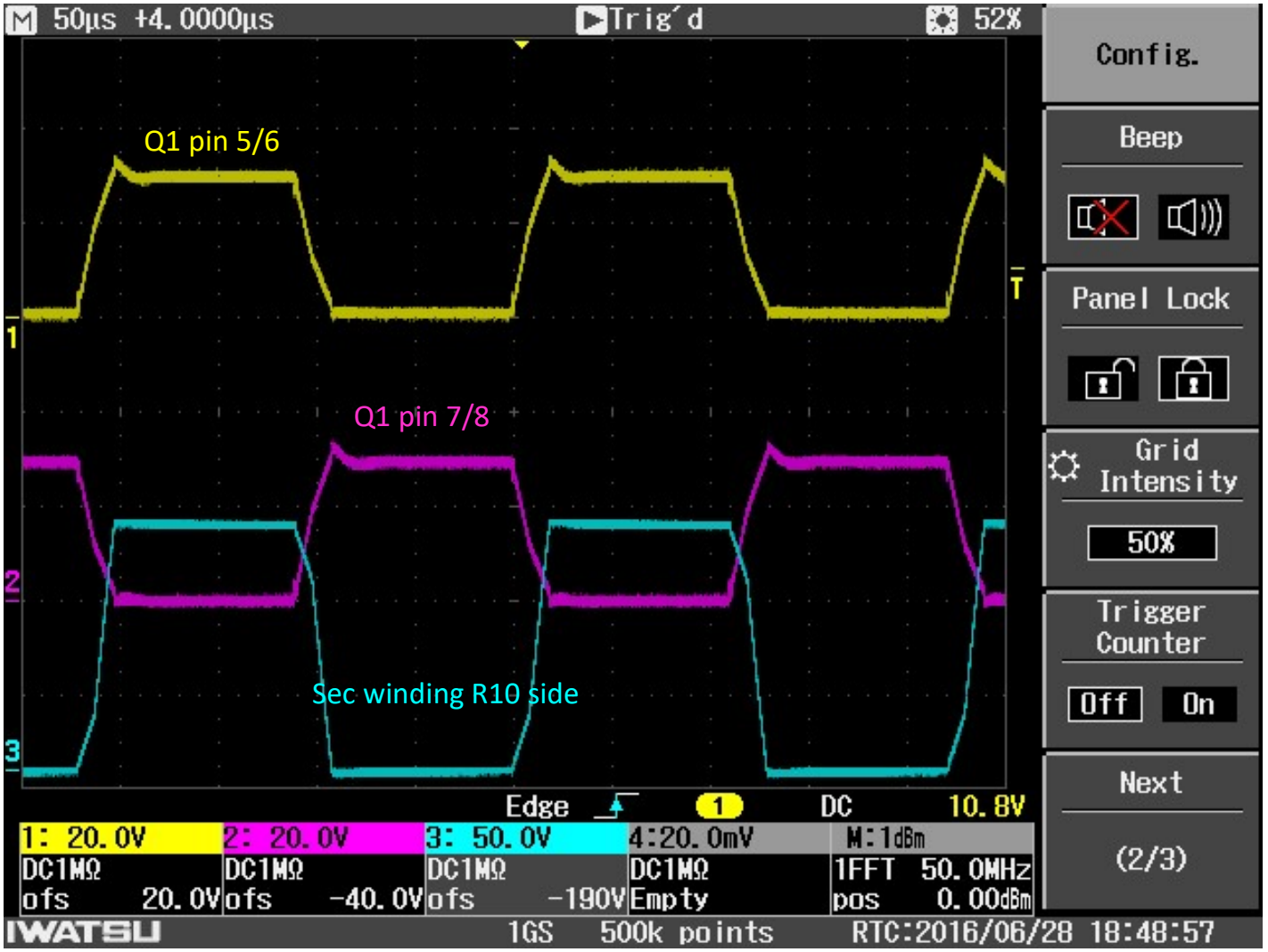
Waveform, switching, 5mA



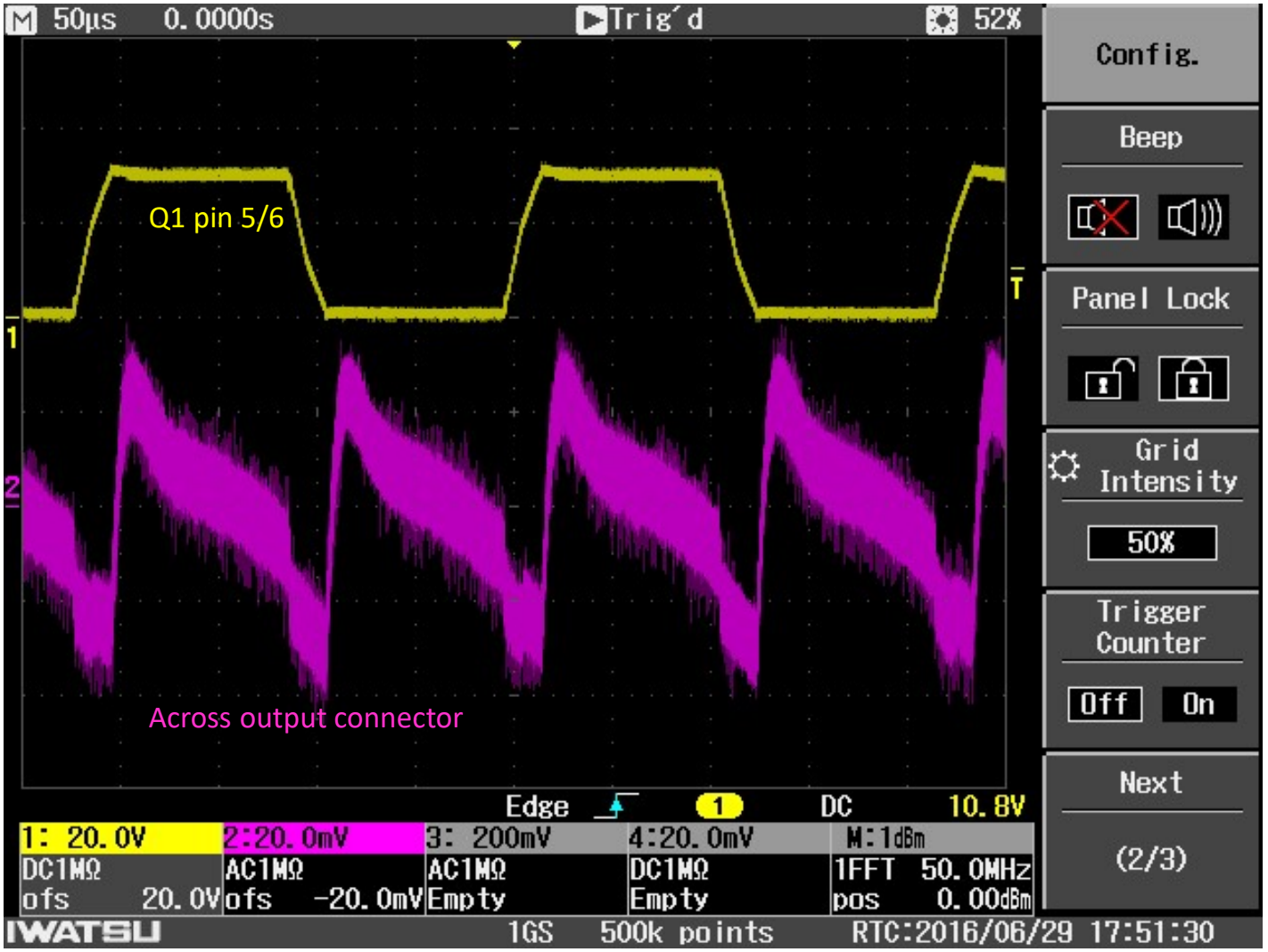
Waveform, switching, 125.9V 5mA



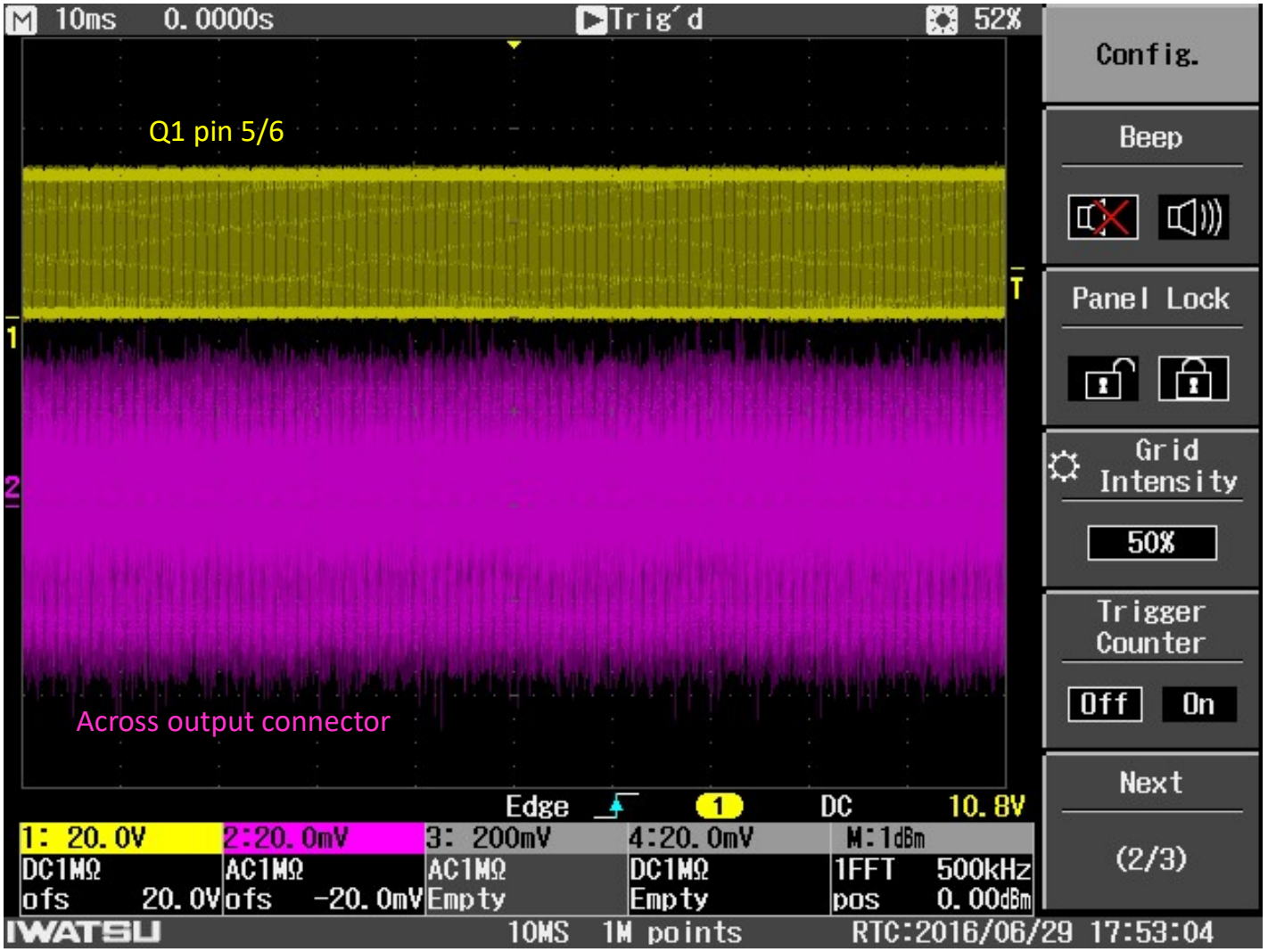
Waveform, switching, 5mA



Waveform, output ripple/noise, 120.1V. 24KΩ resistive load, 5mA

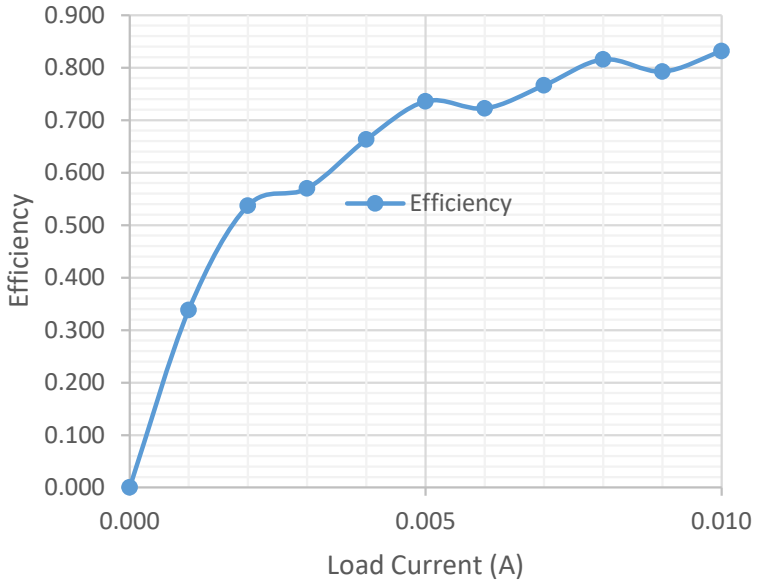


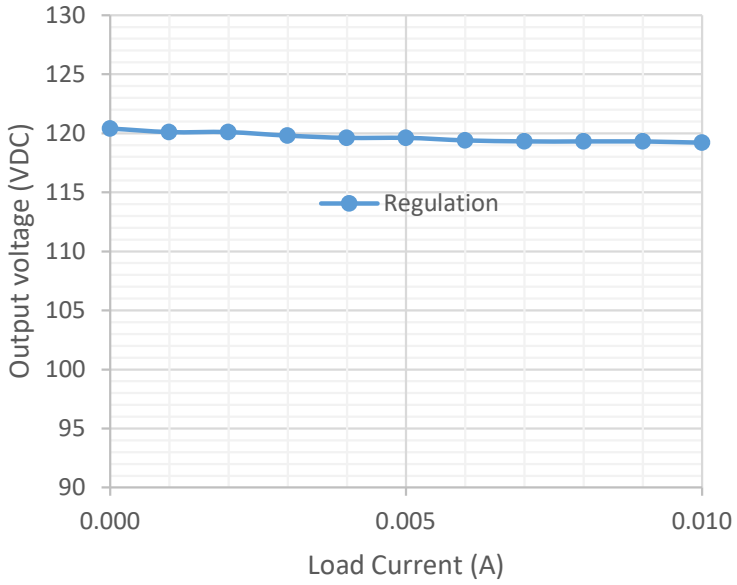
Waveform, output ripple/noise, 120.1V. 24KΩ resistive load, 5mA



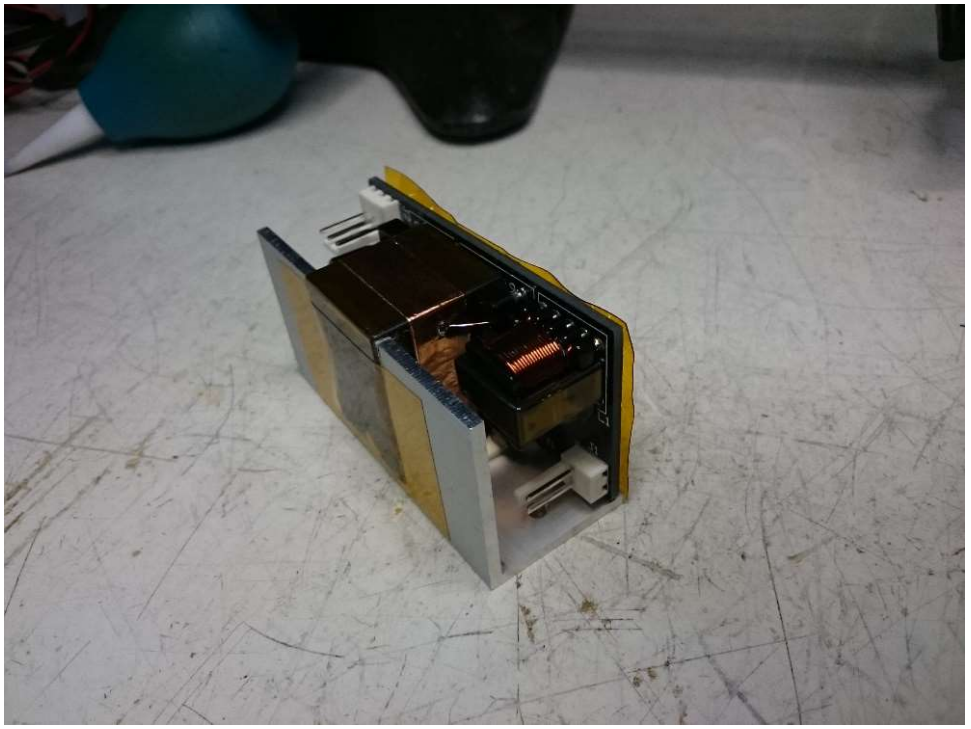
Loaded data

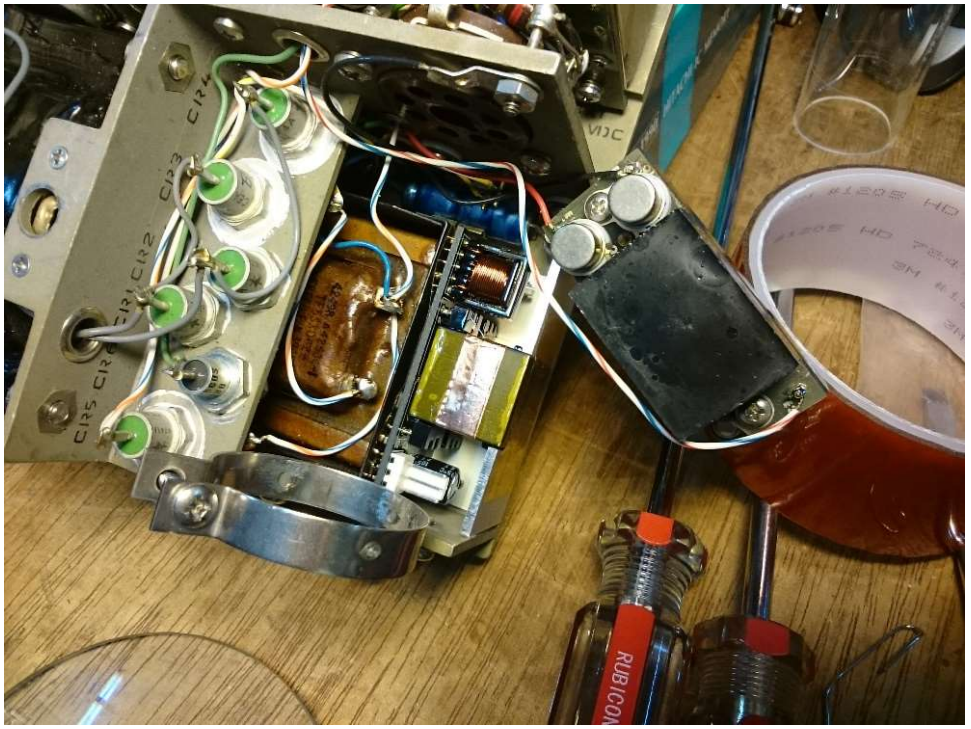
Input		Output		Power		Eff
Voltage	Current	Voltage	Current	Input	Output	
VDC	ADC	VDC	ADC	W	W	
15.0690	1.77E-02	120.4	0.000	2.67E-01	0	0.000
15.0371	2.36E-02	120.1	0.001	3.55E-01	0.1201	0.338
15.0013	2.98E-02	120.1	0.002	4.47E-01	0.2402	0.537
14.9311	4.22E-02	119.8	0.003	6.31E-01	0.3594	0.570
14.8958	4.85E-02	119.6	0.004	7.22E-01	0.4784	0.663
14.8606	5.47E-02	119.6	0.005	8.13E-01	0.598	0.736
14.7903	6.71E-02	119.4	0.006	9.92E-01	0.7164	0.722
14.7558	7.39E-02	119.3	0.007	1.09E+00	0.8351	0.766
14.7185	7.95E-02	119.3	0.008	1.17E+00	0.9544	0.816
14.6400	9.25E-02	119.3	0.009	1.35E+00	1.0737	0.792
14.6082	9.81E-02	119.2	0.010	1.43E+00	1.192	0.832



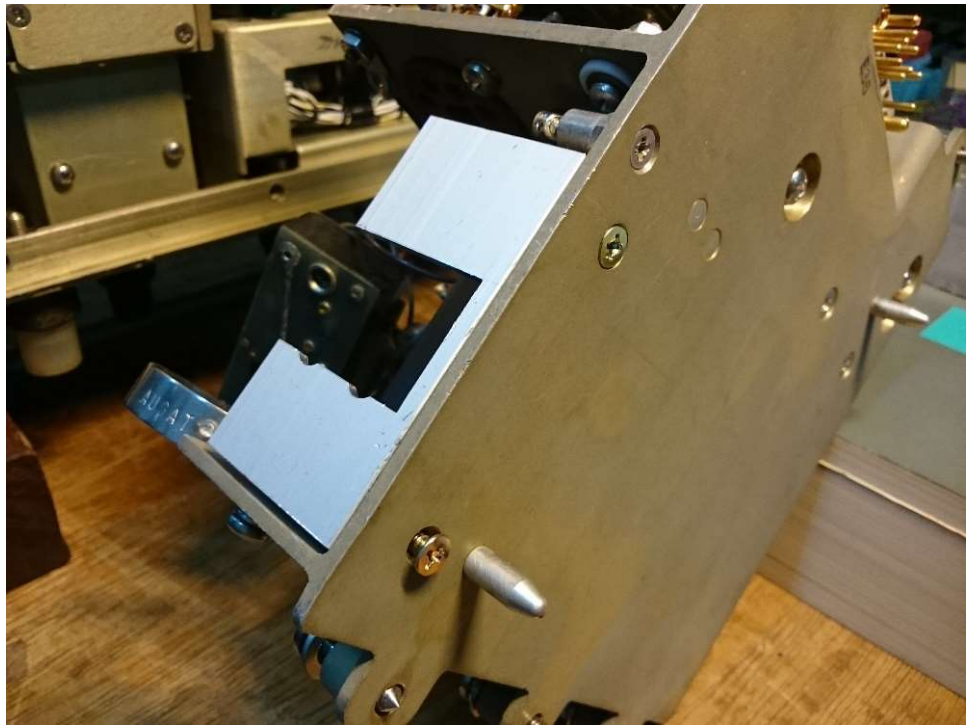


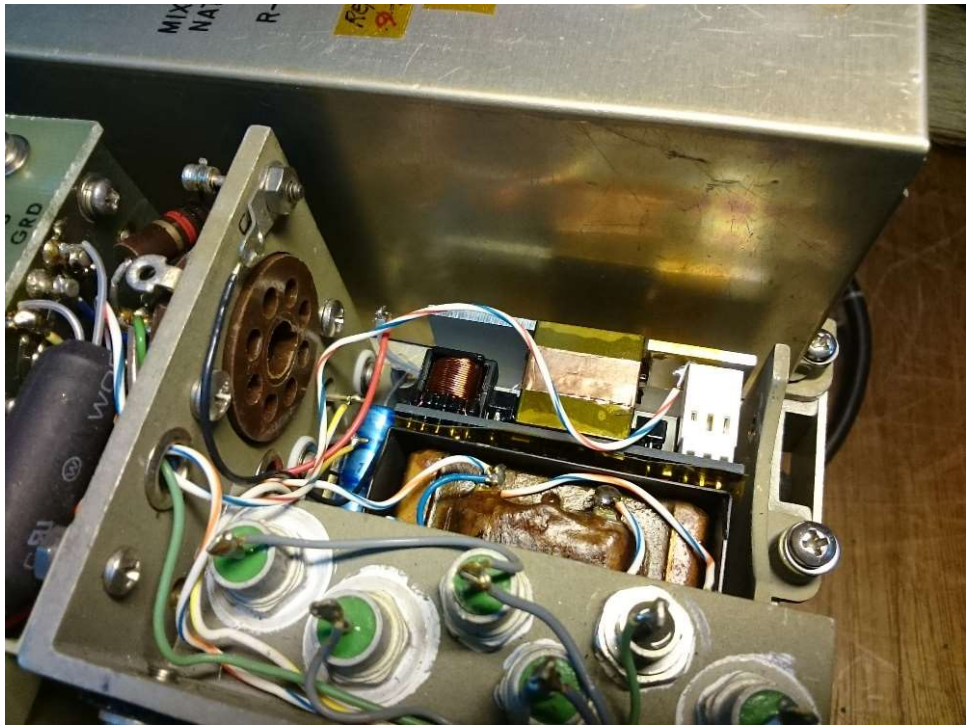
Mount on an Aluminum bracket using double sided tape

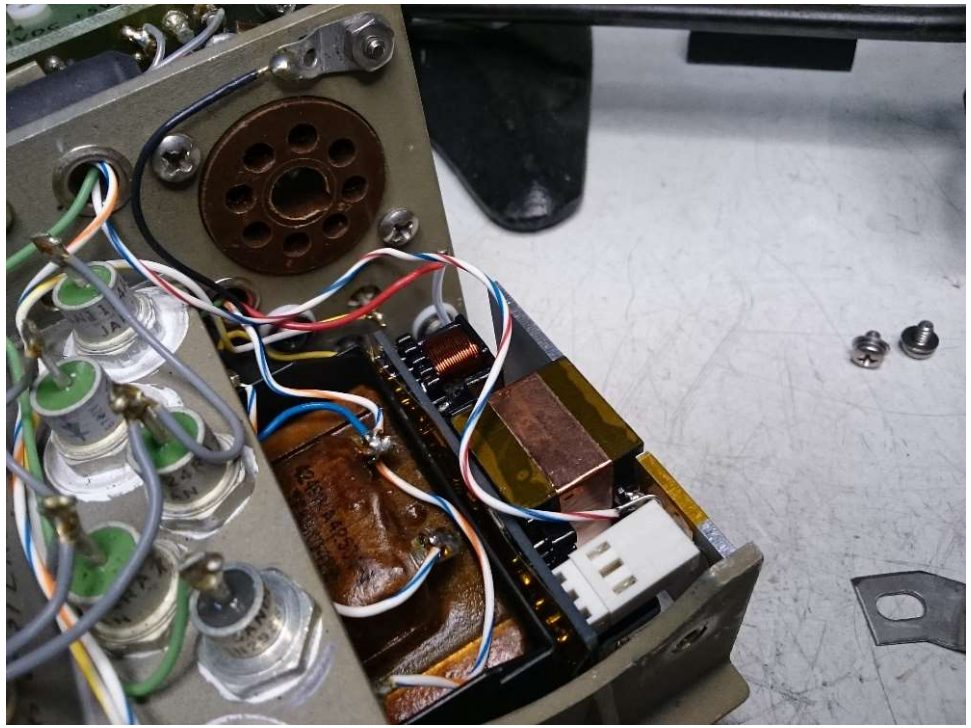


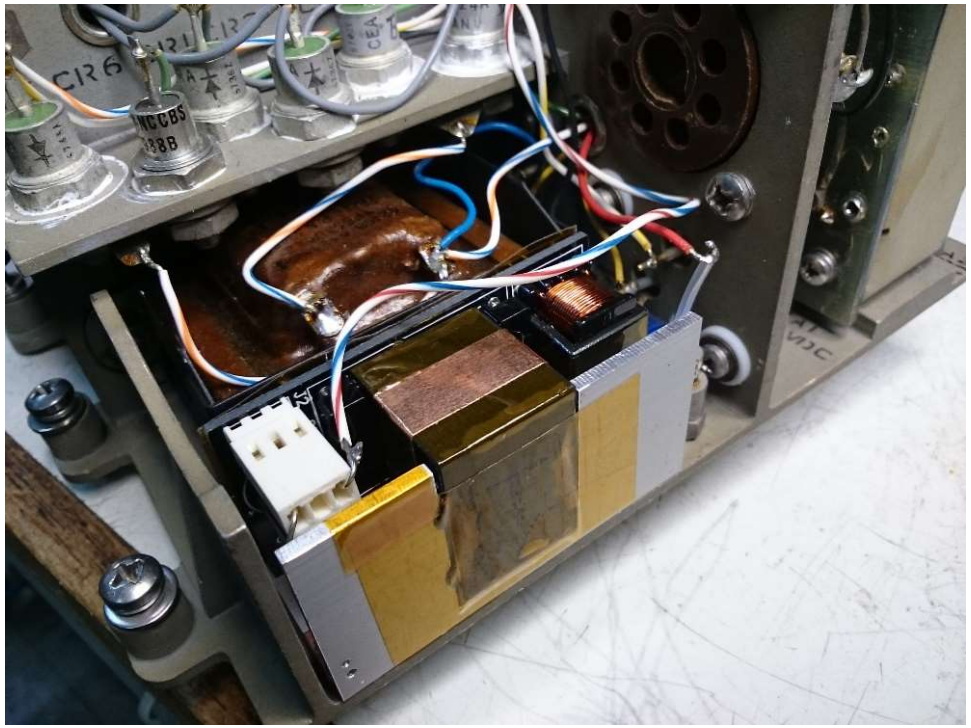


Mount and tested on PSU module, clearance a little critical,









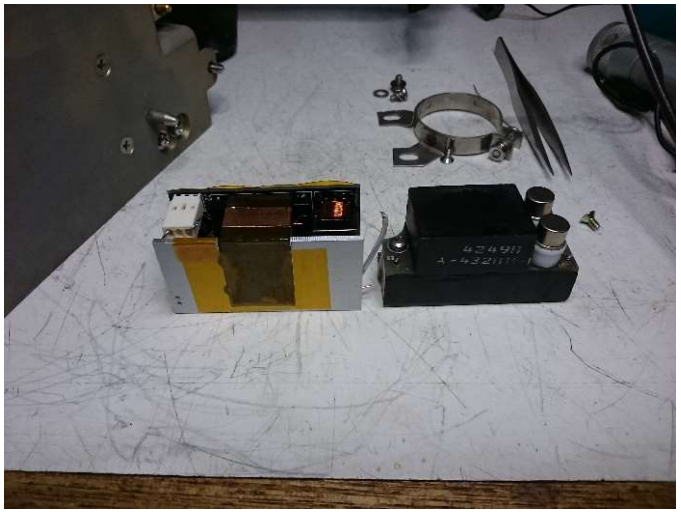
Summary:

- Receiver functions normally after retrofitting with new HV inverter.
- Didn’t give much thought on connector locations, could be further improved
- Additional cutouts on mounting bracket will improve ease of connector entry.
- A low level audible noise still noticeable, transformer needs more aggressive potting

Receiver specific issues:

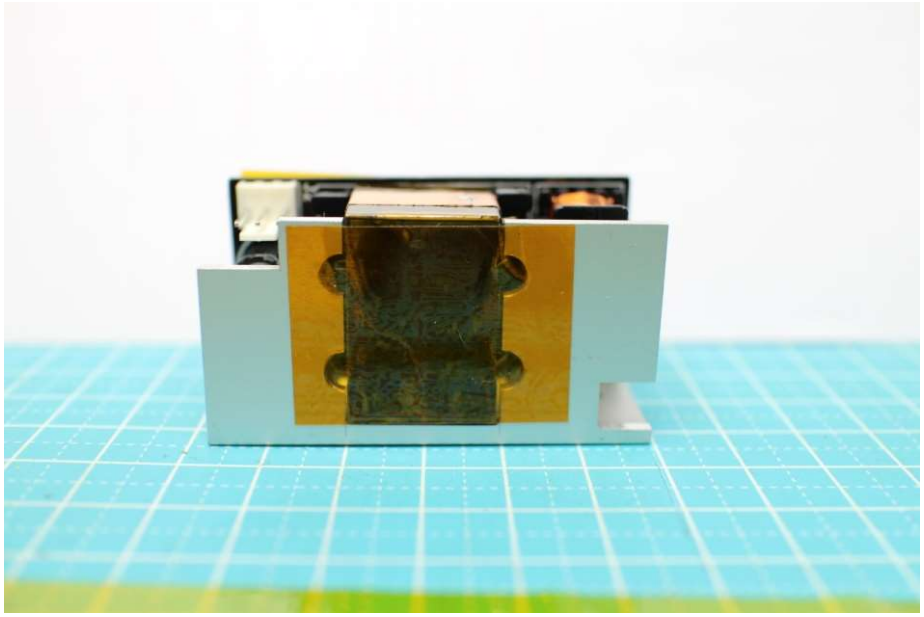
- SN:466 PSU E-cap socket has intermittent contact problem, needs repair.

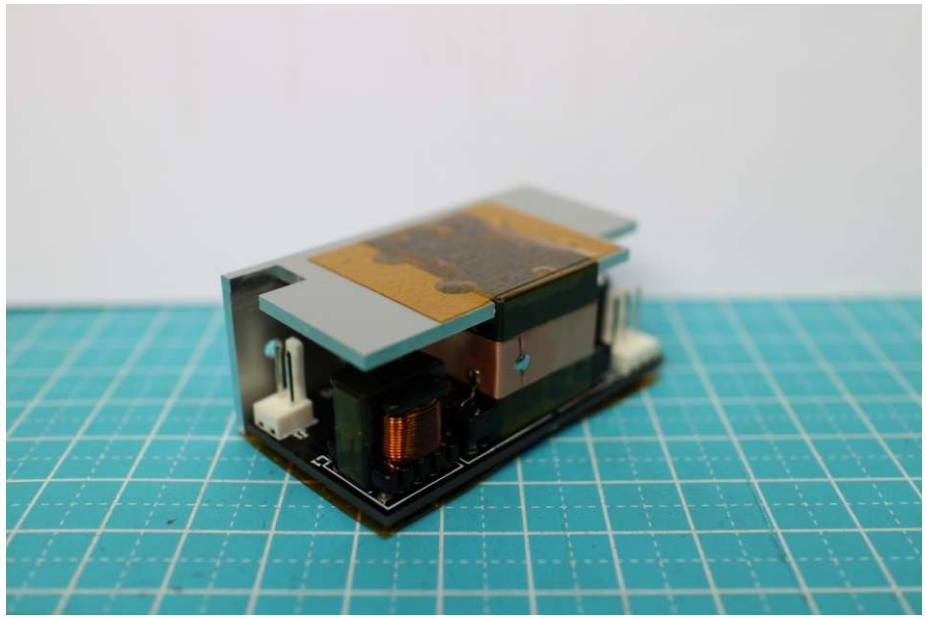
Side by side with original module

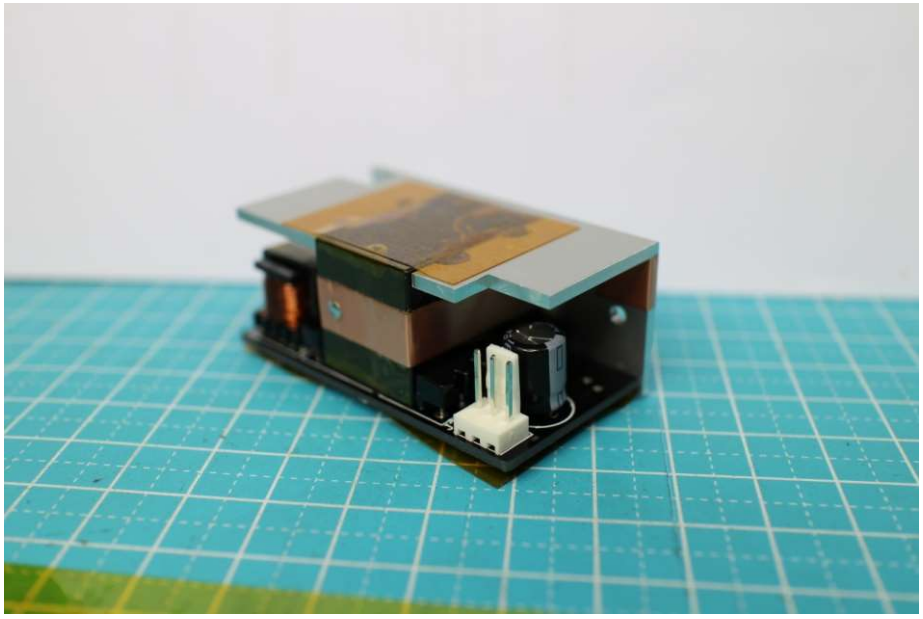



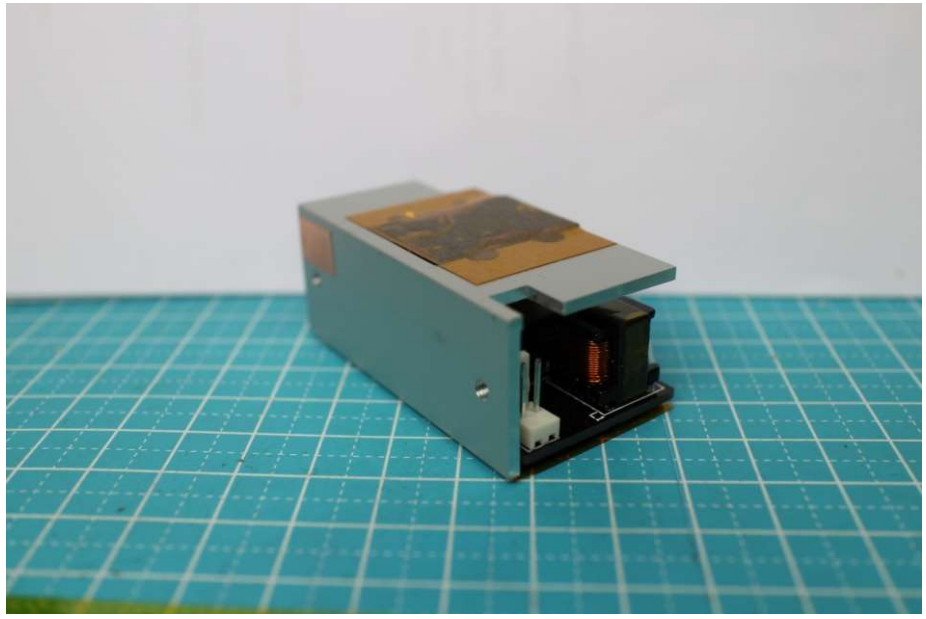


PCB mounted on new bracket









Reference materials

Sch/PCB file Protel99 format

Schematic printout

PCB artwork printout

PCB CAM files

US patent 4,959,765

US patent 4,959,765, DC TO DC CONVERTER USING QUASI-RESONANCE, Alan Weinberg, Sassenheirn,Netherlands, Agence Spatiale Europeenne, France, Sep. 25, 1990